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Sky at Night

152 JANUARY 2018

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Capturing the HUNTER

Take your best astrophotos of winter's iconic constellation

Stranger than we can imagine

10 mindboggling cosmological discoveries

Imaging for science

Real comet research you can do with your own images

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VIDEO INTERVIEW

NASA astronaut Scott Kelly on surviving a whole year in space

WATCH THE SKY AT NIGHT

The search for things that go bang in the Universe

EXCLUSIVE PODCAST

The future of spaceflight, and why we continue to explore the cosmos

Welcome

January brings familiar Orion and unfamiliar frontiers

As we welcome in the New Year there's one aspect of the night sky that many of you will be familiar with – the constellation of Orion. It is a rich treasure trove of photography targets, both for beginners getting their bearings and longstanding observers keen to delve deeper into the night sky. Will Gater looks at the best of them on page 32.

While we must content ourselves with looking out at space from the ground, many missions will be launching directly for it in 2018. On page 67, Elizabeth Pearson is your guide to these coming in the next 12 months. Will they include a manned launch from US soil?

Another question for 2018 is whether it will be the year in which we find a second Earth. I won't be placing any bets just yet, but we're being helped in our search by the increasing ability of artificial intelligence to identify targets in the vast data sets that missions like Kepler and the forthcoming James Webb Space Telescope will generate. Alex Green examines the progress of these neural networks in astronomical research on page 44.

Cosmology is another area in which AI systems can provide powerful tools, tools that might be usefully brought to bear on some of the confounding observations that our Universe has presented us with. On page 38, acclaimed author Marcus Chown looks at some of the most intractable. For some like the riddle of the missing solar neutrinos, there is an answer, but for others we're still in the dark.

Enjoy the issue!

Chris Bramley Editor

PS Our next issue goes on sale on 18 January.

This month's contributors include...

Paul Abel
Astronomer

Paul explains how you can accurately estimate the brightness of variable stars in this month's How To. *Page 79*

Maggie Aderin-Pocock
***Sky at Night* presenter**

Maggie revels in her first sighting of the aurora borealis, and explains the science behind this stunning celestial light show. *Page 21*

Shaoni Bhattacharya
Science writer

Shaoni reviews *A Galaxy of Her Own*, a glimpse into the travails and triumphs of women in space and astronomy. *Page 102*

Marcus Chown
Science author

Marcus guides us through some of the most mindboggling things we've learnt about space. *Page 38*

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Sky at Night Lots of ways to enjoy the night sky...

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Find out what *The Sky at Night* team will be exploring in this month's episode on page 19

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Ⓒ = on the cover

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HOW TO FIND IT

Visit **www.skyatnightmagazine.com/bonuscontent**, select January's bonus content from the list and enter the authorisation code **WATKDX4** when prompted

THERE'S MORE ONLINE

Highlights this month

Interview: Astronaut Scott Kelly

On 2 March 2016, NASA astronaut Scott Kelly landed back on Earth, having spent a year living on the International Space Station. His new book *Endurance* is a memoir of that year in space, detailing the trials and tribulations of life in microgravity. We caught up with Kelly during his recent visit to the UK to find out more about this incredible adventure.

JANUARY'S Virtual Planetarium

With Paul Abel and Pete Lawrence

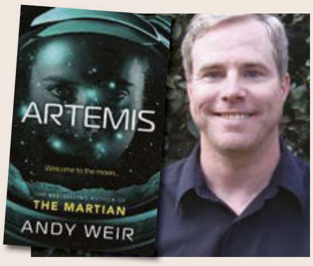
Explore the best of the night sky this month with Paul and Pete.

Watch *The Sky at Night* TV programme

Maggie and Chris turn their attention to the spectacular cosmic events that happen in the blink of an eye.

Exclusive podcast: exploring space

ESA's David Parker and BBC Two's *Astronauts* finalist Tim Gregory discuss why we need to explore the cosmos.



Interview: Andy Weir talks *Artemis*

The Martian author chats about his new novel set on a lunar colony, and the science behind the fiction.

and much more...

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Mystery of the one-armed galaxy

Unusual, unexpected, unexplained and exciting... mysterious phenomena provide astronomers with more clues about the workings of the Universe

HUBBLE SPACE TELESCOPE, 13 NOVEMBER 2017

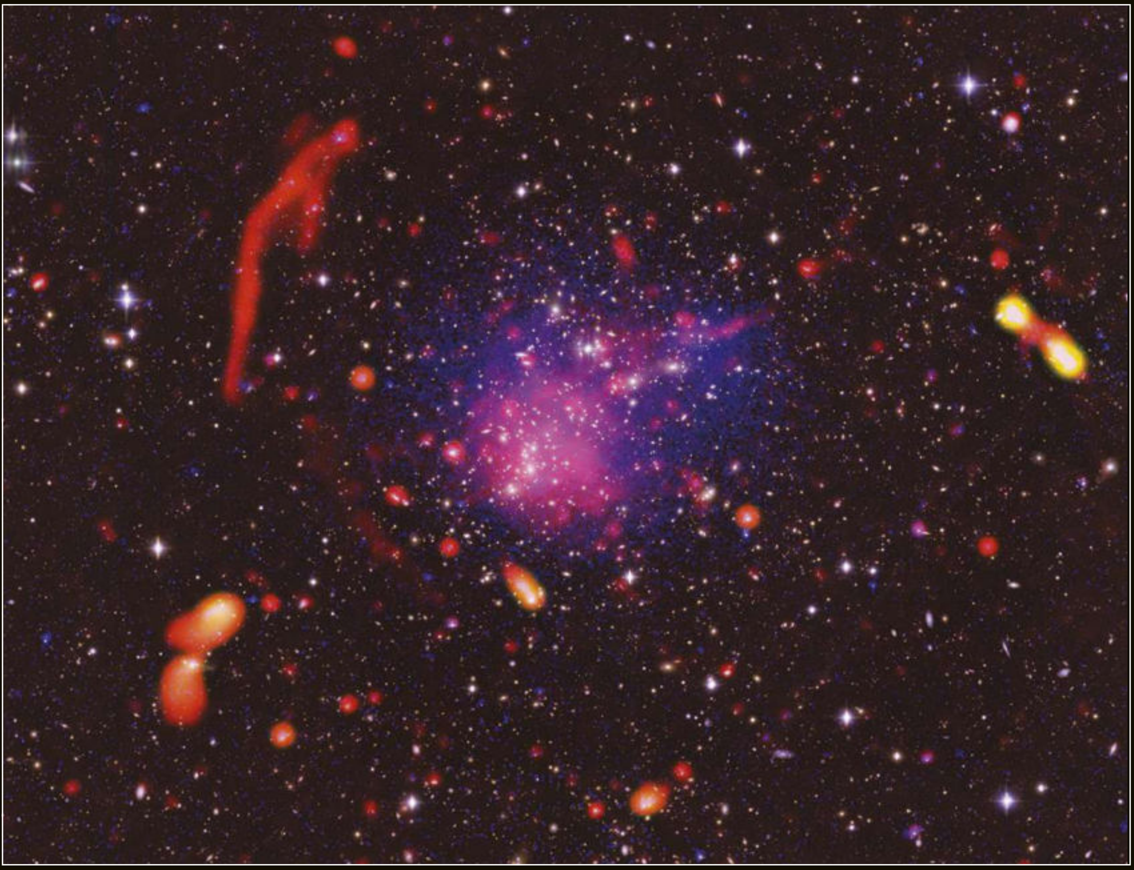
The classic image of a spiral galaxy is of a crisp, symmetrical structure with two arms swirling around a bright core. NGC 4625 bucks the galactic trend as it has just one spiral arm, giving it an odd asymmetry.

This galaxy is about 30 million lightyears away in the constellation of Canes Venatici, close to a dwarf galaxy called NGC 4618. Astronomers are studying NGC 4625 to try and work out why it has such an unusual shape. Could the galaxy have formed this way, or did something happen to it that caused it to lose one of its arms? One theory is that NGC 4625 came into close contact with its nearby dwarf companion at some point in the past, and the interacting gravitational forces distorted its shape.

NGC 4625's disc appears to be four times larger when viewed in ultraviolet light than in the optical light image you see here. This indicates that there is a large number of young, hot stars forming in its outer regions. At about one billion years old, these stars are 10 times younger than the stars in the optical centre.

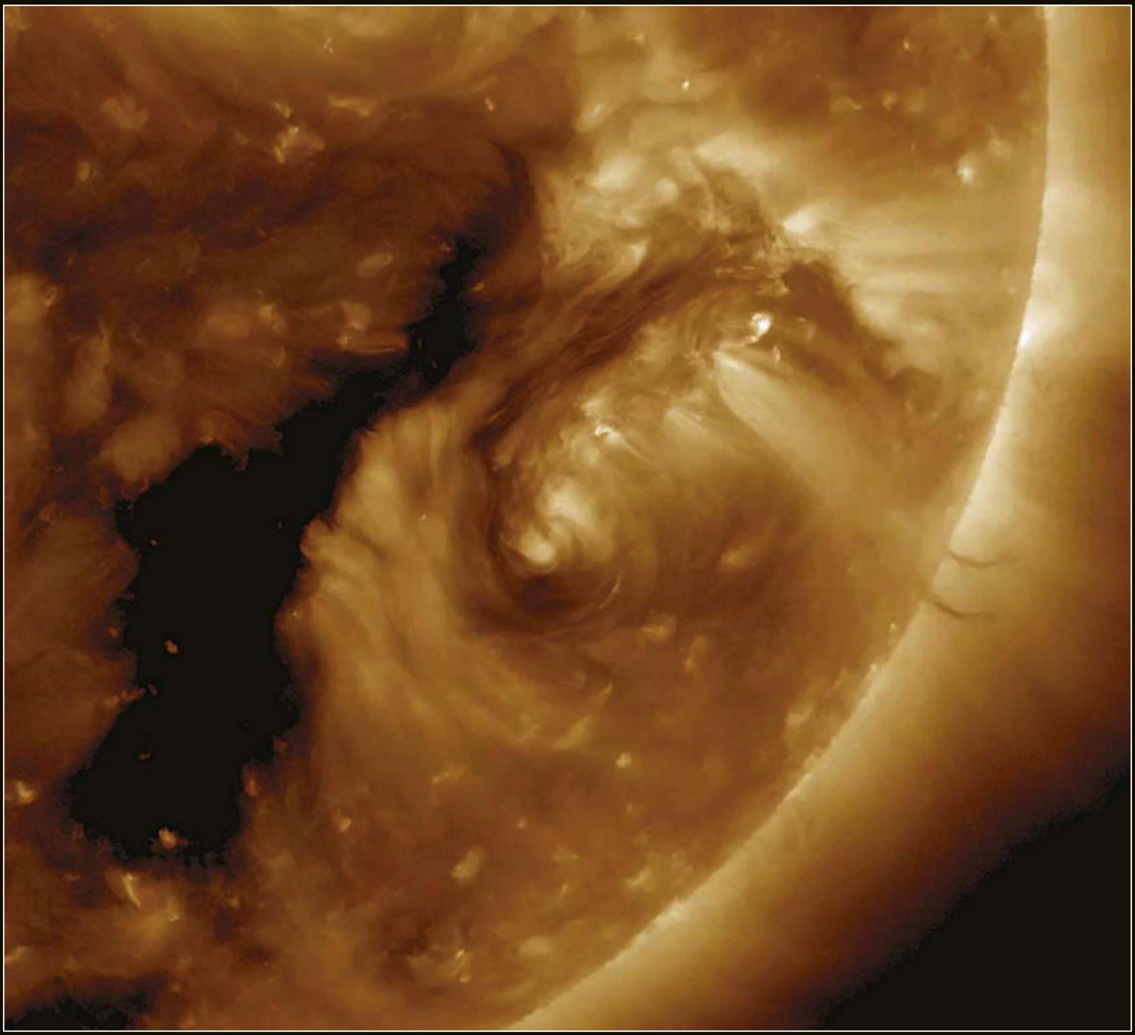
This age differential gives astronomers a clue as to how NGC 4625 lost one of its arms, as galactic interactions are known to trigger bursts of star formation. NGC 4618 could indeed be the culprit. It may have come too close to NGC 4625 and torn off one of its arms, triggering the formation of a new batch of stars in the process.

Colliding clusters ▶



KARL G JANSKY VERY LARGE ARRAY/ CHANDRA X-RAY OBSERVATORY/ SUBARU TELESCOPE/ VERY LARGE TELESCOPE, 7 NOVEMBER 2017

Galaxy clusters are some of the most massive objects in the Universe, so they create quite a scene when they collide. Giant galaxy cluster Abell 2744, some four billion lightyears away, is the product of two (or perhaps three) such events. The collisions produce enormous amounts of energy, seen as bright radio emissions in red and orange, and heat as X-rays in purple.



◀ Swirl on the Sun

NASA SOLAR DYNAMICS OBSERVATORY, 29-31 OCTOBER 2017

In the middle of this image of our Sun is a dark filament swirling around an active region. These filaments are clouds of charged particles floating above the Sun and held in place by magnetic forces, but to see one shaped like a circle is a rare occurrence. The black area to the left is a coronal hole, an 'open' region created by magnetic field lines stretching out from the solar surface.

YOUR BONUS CONTENT

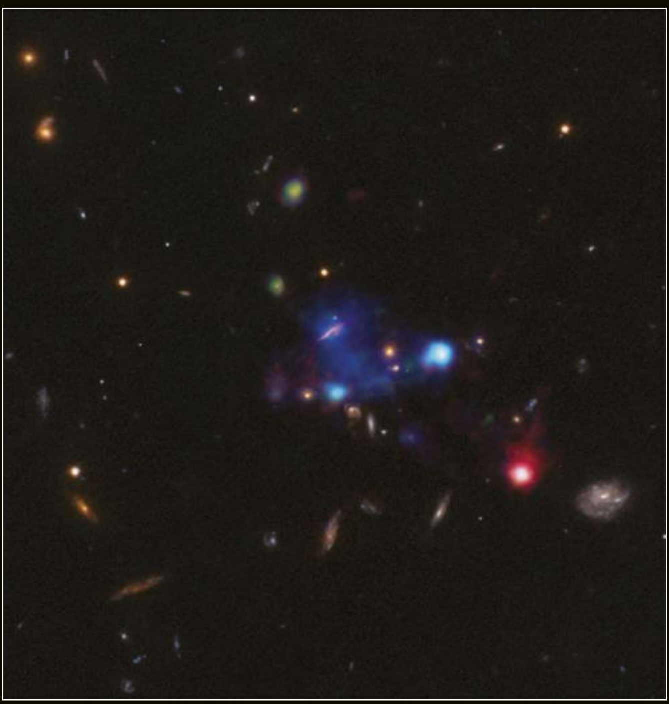
A gallery of these and more stunning space images

PEARCE ET AL.; BILL SAXTON, NRAO/AUI/NSF; CHANDRA, SUBARU; ESO, NASA/GSFC/SOLAR DYNAMICS OBSERVATORY, NASA/JPL-CALTECH/SWRI/MSSS, ESO/T. CONTINI (IRAP, TOULOUSE), B. EPINAT (LAM, MARSEILLE), ALMA (ESO/NAOJ/NRAO), TAKIGAWA ET AL.

A pearl of a storm ▶

JUNO SPACECRAFT/ GERALD EICHSTÄDT & SEÁN DORAN, 24 OCTOBER 2017

NASA's Juno spacecraft continues to beam back incredible images of Jupiter, revealing this stormy gas giant in greater detail than we've seen before. The white oval in the brown band near the lower right corner of this image is a giant storm. It's one of the 'String of Pearls', the name given to eight rotating storms located in the planet's southern hemisphere.



▲ Gassy galactic bubble

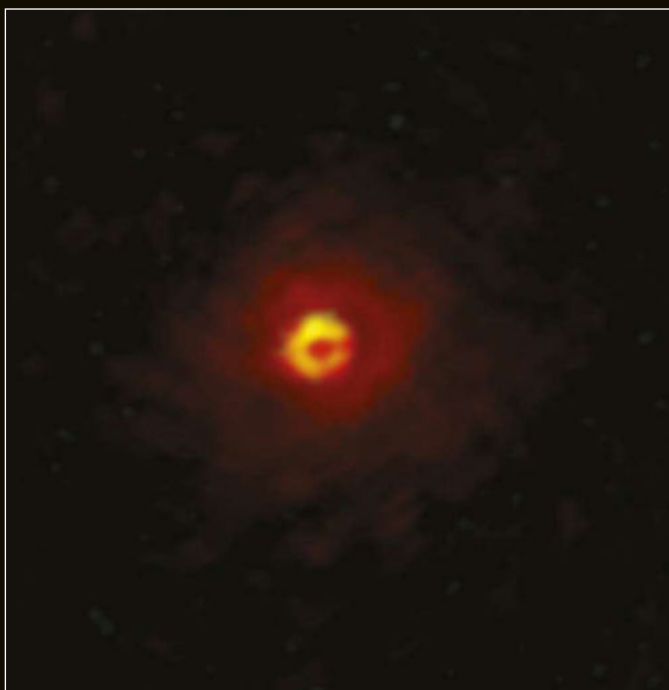
VERY LARGE TELESCOPE, 13 NOVEMBER 2017

A colourful, bright bubble of ionised gas stands out against the darkness in this image captured by the MUSE instrument, a spectrograph that splits light into a spectrum to reveal cosmic features that would otherwise be invisible to the naked eye. The bubble contains 10 galaxies and is part of galaxy group COSMOS-Gr30, 6.5 billion lightyears away. It is the largest of its kind ever discovered.

▼ Dusty dying star

ATACAMA LARGE MILLIMETER/SUBMILLIMETER ARRAY, 9 NOVEMBER 2017

W Hydrae is an asymptotic giant branch (AGB) star, a class of old, bright stars that give off mass via streams of charged particles known as stellar winds. Using telescopes like ALMA, astronomers can obtain more detailed images of dusty stars such as these and learn more about the chemical workings of the Universe.

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Bulletin

The latest astronomy and space news written by **Elizabeth Pearson**

PLUS CUTTING EDGE

Our experts examine the hottest new astronomy research papers

The extreme, elongated shape of the asteroid is thought to be unique

ESO/M. KORNMESSER

INTERSTELLAR ASTEROID visits our Solar System

The cigar-shaped body came within 24 million km of Earth

In mid-October humankind spotted its first interstellar asteroid – a space rock that had travelled from beyond the bounds of our Solar System. The cigar-shaped object, thought to be 10 times as long as it is wide, was first detected by the Pan-STARRS1 telescope on the Hawaiian island of Maui, and passed within 24 million km of Earth. It's since been named 'Oumuamua, a Hawaiian word meaning 'a messenger from afar arriving first'.

Astronomers began observing the object thinking that it was a comet, but its steep trajectory and rapid speed (up to 87.3km/s), combined with the fact that it didn't produce a tail as it passed the Sun, convinced them that the body was not only an asteroid, but one that originated far from our cosmic backyard.

"Needless to say, we dropped everything so we could quickly point the Gemini telescopes at this object immediately after its discovery," says Laura Ferrarese, director of the Gemini Observatory. The Gemini South Telescope in Chile measured the brightness of the object over several nights, revealing that 'Oumuamua took 7.3 hours to spin on its axis, during which time its brightness varied by a factor of 10. It's this unusually big variation in brightness that led scientists to conclude that 'Oumuamua is so long and thin, with a length in the region of 400m.

Such interstellar visitors could pass through the Solar System at least once a year.

"For decades we've theorised that such interstellar objects are out there, and now – for the first time – we have direct evidence they exist," says Thomas Zurbuchen, associate administrator for NASA's Science Mission Directorate. "This history-making discovery is opening a new window to study the formation of Solar Systems beyond our own."

▸ **See Comment, right**

COMMENT
by Chris Lintott

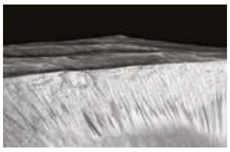
Our theories of how planetary systems form tell us that much material must be ejected early on – our own Kuiper belt, for example, is expected to have only 1/1,000th of the mass it once did – and so the presence of 'Oumuamua is not a complete surprise.

What is strange is how odd this visitor is. Most people would have expected an interstellar comet, not an asteroid – it's easier to fling material out from the icy edge of a planetary system, where comets lurk – and that shape is completely unprecedented.

Astronomers react to mysteries by proposing ideas. Some want to send a mission chasing after it (they would need a very big rocket) while others half-jokingly decided it was a spacecraft (that slow rotation is not enough to produce a decent artificial gravity, mind you). Neither is likely, but we'll be telling tales about this strange visitor for a long, long time.

CHRIS LINTOTT co-presents *The Sky at Night*

NEWS IN BRIEF



DRY MARTIAN SLOPES

Dark seasonal stripes on Mars have been identified as flows of dust and sand. A new study on recurring slope lineae (RSL) – long lines that appear to run down Martian slopes during the winter – examined the angle and length of 151 of these features.

"We've thought of RSL as possible liquid water flows, but the slopes are more like what we expect for dry sand," says Colin Dundas from the US Geological Survey. "This new understanding of RSL supports other evidence that shows that Mars today is very dry."

SPYING ON RED GIANTS

Astronomers have observed surface details on an aging, solar-mass star for the first time. The images of the red giant, taken by ALMA, show that there are surprisingly hot gases in the star's chromosphere – the layer above the star's surface. One explanation is that powerful shockwaves in the star's atmosphere are driving the surface to much higher temperatures than anticipated. Alternately, the star could have been experiencing a giant flare at the time.

The supernova was supposed to fade away; that it hasn't has surprised astronomers

The star that DIED TWICE

This supernova "breaks everything we thought we knew"

Like a celestial horror villain, an exploded star has burst back to life after 50 years. This supernova, which exploded in 2014 but only recently faded, may be the revived remnant of a previous explosion witnessed in 1954.

In September 2014, the intermediate Palomar Transient Factory team at the University of California, Santa Barbara (USCB) discovered a new supernova in a distant galaxy named iPTF14hls. At first it appeared to be a run-of-the-mill Type II-P supernova, one caused by the rapid collapse of a massive star, and should have dimmed after 100 days or so. Instead, after a few months it began to grow in brightness, and remained bright for around 600 days.

"Supernova iPTF14hls may be the most massive stellar explosion ever seen," says Lars Bildsten, director of USBC's Kavli Institute for Theoretical Physics. "For me, the most remarkable aspect of this supernova was its long duration, something we have never seen before. It certainly puzzled all of us as it just continued shining."

When consulting archival data, the team found that a supernova had previously been seen in 1954 in the same location. Somehow, the star had survived to explode again 50 years later. This earlier explosion could be an important clue to the supernova's true identity.

Some researchers suggest that this is the first observed example of a pulsational pair-instability supernova. These occur when massive stars become hot enough to convert energy into matter and antimatter, creating an explosion that blows off the star's outer layers while leaving the core intact. The process could repeat itself for decades.

"These explosions were only expected to be seen in the early Universe and should be extinct today," says Andy Howell who leads the supernova group at the Las Cumbres Observatory. "This is like finding a dinosaur still alive today. If you found one, you would question whether it truly was a dinosaur."

However, it could be that iPTF14hls is a completely new type of supernova.

"This supernova breaks everything we thought we knew about how they work," says Iair Arcavi from UCSB, the study's lead author. "It's the biggest puzzle I've encountered in almost a decade of studying stellar explosions."

https://lco.global/news

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Sun represents wider Universe

Chemistry in a nearby galaxy cluster matches up to that of our Sun

The Sun may be more typical of the Universe's elemental composition than previously believed, according to newly released data taken by the Japanese X-ray astronomical satellite ASTRO-H.

The satellite measured the abundances of elements such as chromium, manganese, iron and nickel in the hot plasma of the nearby Perseus Galaxy Cluster, located 240 million lightyears away – and found its composition to be nearly identical to our Sun. It was originally thought the stars within Perseus's elliptical galaxies would have completely different chemistries to the Sun, which is in a spiral. That they don't suggests the Sun is more representative of the Universe than first believed.

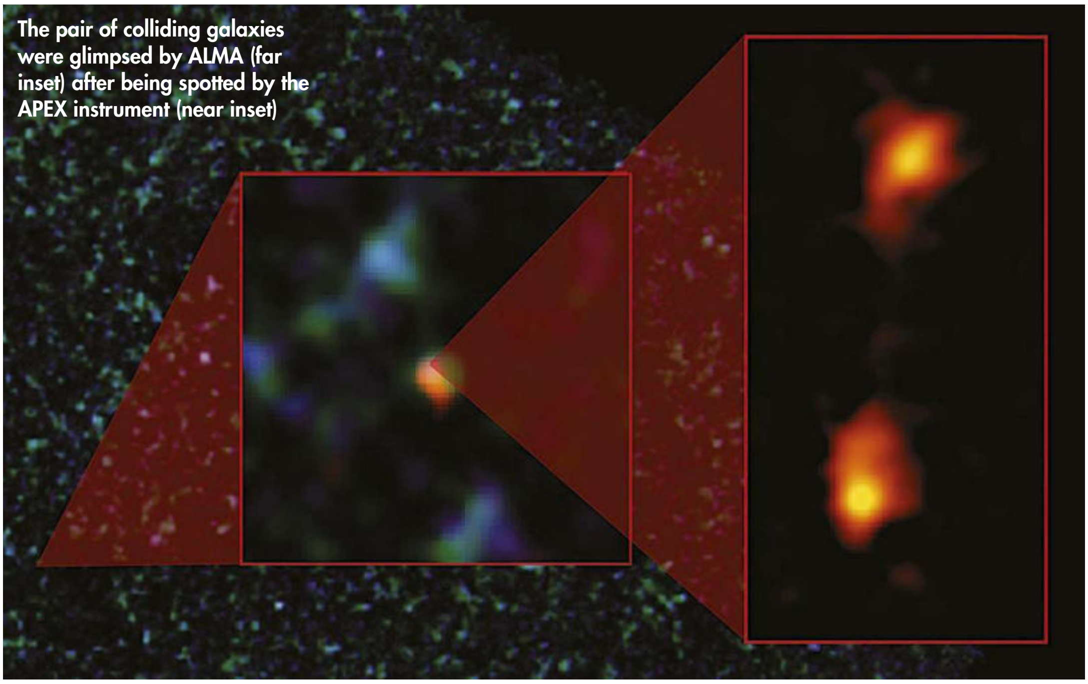
The discovery was only possible due to ASTRO-H's high resolution spectroscopy, which could clearly differentiate between iron and nickel, something previous instruments had failed to do.
https://saturn.jpl.nasa.gov

▲ ASTRO-H was launched in February 2016 and lost a month later; these findings were made using legacy data

CLASH OF THE TITAN GALAXIES

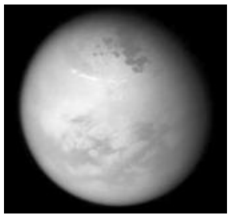
A pair of huge, extremely bright galaxies in the distant Universe have been seen smashing together by ALMA in what could be the most extreme galaxy merger ever witnessed. The pair are 12.7 billion lightyears away, meaning that they are being viewed as they were during their infancy.

They contain 50 times the amount of star forming gas as the Milky Way, enough to produce stars 1,000 times faster than our own Galaxy. The collision would have kick-started intense star formation, leading the pair to grow into a massive galaxy in the current-day Universe. "Finding these galaxies – about 30,000 lightyears apart – helps astronomers to understand how very extreme structures form, as they continue to birth stars and become even more massive," says Dominik Reichers from Cornell University who led the study. "These galactic progenitors help us to understand massive galaxies in the present day, as we've tried to understand how these actually form."
www.almaobservatory.org



The pair of colliding galaxies were glimpsed by ALMA (far inset) after being spotted by the APEX instrument (near inset)

NEWS IN BRIEF



TITAN'S WINTER WARMER

The winter skies of Titan, Saturn's largest moon, are unseasonably cold. On the rocky planets of the Solar System, high-altitude air over the polar regions is usually warm during winter, no matter how cold it may be on the ground. But according to an analysis of Cassini data, the cocktail of elements in Titan's atmosphere means that the temperature drops dramatically.

HELP HUNT FOR GRAV WAVES

The research teams looking for the sources of gravitational waves hope to enlist members of the public to aid the search. When a new detection is made, the team from Cardiff University and Las Cumbres Observatory will release the follow-up observations to members of the public, who will look for any changes in the pictures.

"Through our project anyone around the world will be able to help find the sources of gravitational waves, and investigate them further," says Chris North from Cardiff University.

CUTTING EDGE

Our experts examine the hottest new research

Missing galaxies may not be missing

The lack of small satellites around the Milky Way has long been a problem – but all may not be as it seems

▲ **The Small Magellanic Cloud is one of our Galaxy's largest satellites**

ROBERT SCHULZ/CCDGUIDE.COM

In the past couple of decades, we've converged on a new standard model of cosmology. This theory has its problems: it depends on the existence of mysterious dark matter and even more enigmatic dark energy, but it keeps passing observational tests.

It's not surprising, then, that attention focuses on any possible discrepancy between the predicted and the real Universe. The most famous case is the 'missing satellites' problem. Large simulations of the Universe that use the standard model of cosmology predict that large galaxies such as the Milky Way should be surrounded by many more small satellite galaxies than we see.

The Milky Way does have satellites, as anyone who has been to the southern hemisphere and seen the beautiful Large and Small Magellanic Clouds will tell you. There just aren't enough detected to match the predictions, but a new paper argues that we shouldn't give up just yet. The missing satellites are small, and thus hard to detect. Just because we don't see them, it doesn't mean they don't exist: even deep surveys of the sky can't claim to have carried out a complete census. The Sloan Digital Sky Survey, which mapped the northern sky and which is the go-to dataset for such studies, is only reliable out to a distance one-fifth of the way to that of the most distant predicted systems.

Making matters worse is the likely composition of galaxies. Once you're smaller than about a hundredth of the mass of the Milky Way, a limit of about a billion solar masses or so, it's hard to reach the density of gas that is required to kick-start star formation. That means most of these smaller satellites, precisely those which might be hiding, will be even dimmer than expected and harder to detect.

> ***"Large simulations predict that galaxies such as the Milky Way should be surrounded by more small satellite galaxies than we see"***

One way to deal with this situation is to build deeper surveys, capable of spotting even the puniest satellite galaxies. I hope we'll do that one day. In the meantime, Stacy Kim from Ohio State University and colleagues Annika Peter and Jonathan Hargis have decided to get on with it, building a complicated statistical model which can predict, from the data we already have in hand, the number of such galaxies that are out there.

Essentially, they make sensible guesses for how the number of satellites we see relates to the number of (mostly smaller) systems that are out there still to be discovered. This is one of those tasks that sounds simple, but is actually devilishly complicated, with the relationship between the mass of a galaxy and the number of brightly shining stars it contains very difficult to constrain. Yet the results are stunning.

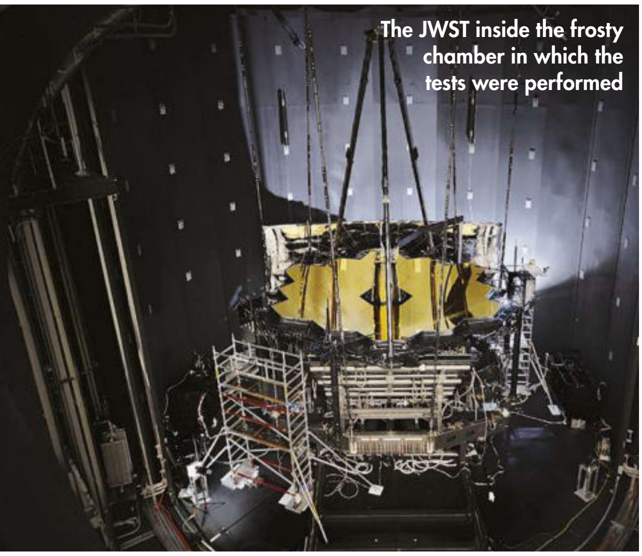
For sensible guesses as to how the Universe behaves, the authors find that the number of satellites around the Milky Way matches the predictions of the standard cosmological model. There is, in fact, absolutely no missing satellite problem, and while we should still check by looking, it seems our best guess as to what the Universe is really like has passed another test.

CHRIS LINTOTT is an astrophysicist and co-presenter of *The Sky at Night* on BBC TV. He is also the director of the Zooniverse project.

CHRIS LINTOTT was reading *There is no missing satellites problem* by Stacy Y Kim, Annika HG Peter and Jonathan R Hargis.
Read it online at https://arxiv.org/abs/1711.06267

JWST passes cryogenic tests

The huge telescope remains on track for a 2019 launch



The JWST inside the frosty chamber in which the tests were performed

The James Webb Space Telescope (JWST) completed its final vacuum tests on 18 November, after almost 100 days in a cryogenic chamber.

The tests, the first undertaken on the completed telescope assembly, were made to ensure it would function correctly in the cold vacuum of space. They included an alignment check on the 18 gold-coated primary mirror segments to check that they will perform as a single mirror while in its orbit. In space, the telescope will be kept at –240°C by using a tennis court-sized sunshield.

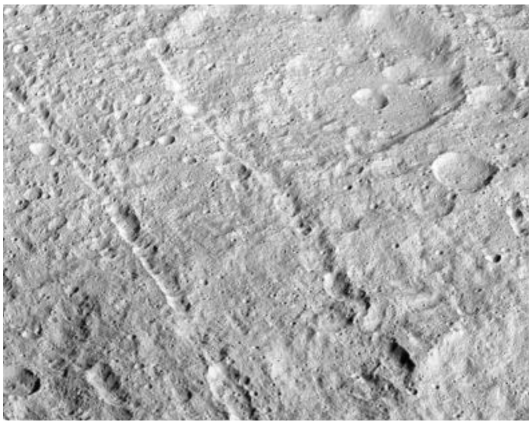
The space telescope was also subjected to an unexpected ordeal on 25 August 2017, when Hurricane Harvey battered the testing facility in Texas. Fortunately, its checks went on uninterrupted. The telescope elements will be integrated with the spacecraft bus in time for a spring 2019 launch.
https://jwst.nasa.gov

Getting to the bottom of pit chains

Strings of craters on the surface of dwarf planet Ceres known as pit chains could be caused by movements in its interior, according to recent interpretations of images taken by the Dawn spacecraft.

Pit chains are rows of irregular craters without a raised rim that can reach over 1km in length. The images from Dawn support the idea that hundreds of millions of years ago material beneath Ceres pushed up to the exterior. The material could have flowed to the surface as it was less dense than that surrounding it, giving clues to Ceres's internal make-up.

"As this material moved upward from underneath Ceres's surface, portions of Ceres's outer layer were pulled apart, forming the fractures," says Jennifer Scully from the Dawn science team.
https://dawn.jpl.nasa.gov



▲ Pit chains on Ceres like these – the Samhain Catenae – could be the telling sign of subsurface fractures

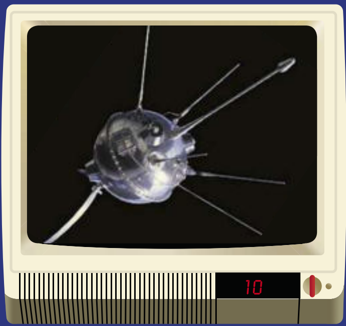
LOOKING BACK THE SKY AT NIGHT

January 1959

On 12 January 1959, Patrick Moore and *The Sky at Night* looked at the recent advances made by the Soviet Union's space programme a week after the nation launched the Luna 1 spacecraft.

The probe was intended to impact on the Moon, becoming the first man-made object to touch another world. That honour would instead go to its successor, Luna 2, as an incorrectly timed upper-stage burn meant that Luna 1 missed the moon by 5,900km, instead making it the first space probe to leave geocentric orbit.

Luna 1 was very simple in design: it was a spherical spacecraft with basic radio equipment, a magnetometer, a Geiger counter, a scintillation counter and a micrometeorite detector. Though the probe missed its target, it still revealed the absence of a lunar magnetic field and made the first direct observations of the solar wind.



▲ Luna 1 would have crashed down on the Moon had all gone to plan

CASSINI IMAGING TEAM;SSI/JPL/ESA/NASA, NASA/CHRIS GUNN, HNASA/JPL-CALTECH/UCLA/MPS/DLR/IDA, ALEXANDER MOKLETSOV

NEWS IN BRIEF

FIREBALL QUARTET SETS SKY AFLAME

Four meteors brighter than Venus were spotted within 10 hours of each other on the night of 14-15 November and reported by 1,320 witnesses. The first pair of space rocks were spotted over Germany and France, whilst the remaining two in the skies of Ohio and Arizona in the US.

They weren't the only exciting sightings of the month. On the night of 24-25 November, another pair of fireballs passed over the south of the UK, with over 100 sightings reported.

PRIVATE PROBE TO ENCELADUS?

Breakthrough Starshot founder Yuri Milner has announced plans for a privately funded mission to Enceladus, which would search for life in the jets of water erupting from it.

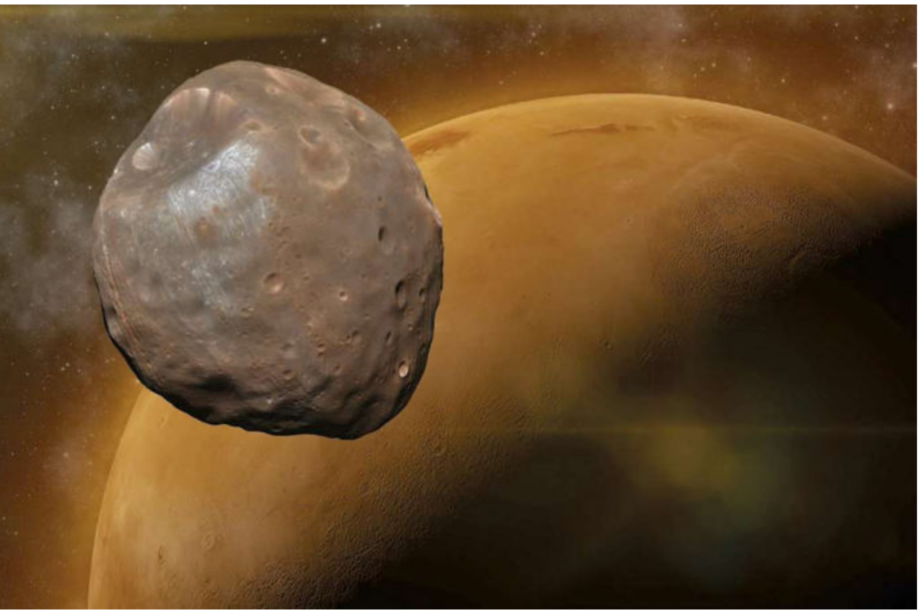
"We formed this little workshop around this idea: can we design a low-cost, privately funded mission to Enceladus which can be launched relatively soon, and that can look more thoroughly at those plumes to try and see what's going on there?" says Milner.

CUTTING EDGE

Our experts examine the hottest new research

The impact of impacts on small moons

The fallout from large meteors could make moons appear much older than their years



▲ Phobos's proximity to Mars makes the moon particularly prone to craters being created by sesquinary impacts

ISTOCK, NASA/JPL-CALTECH/UNIVERSITY OF ARIZONA

When a meteor impacts a moon, it kicks up a lot of material, or ejecta, which then either rains back down on the surface or escapes into space. Sometimes, however, the conditions are just right and the ejecta enters orbit around the moon's parent planet before re-impacting the moon, creating what are known as sesquinary craters.

As well as being inherently pleasing to say, sesquinary craters are also an important factor shaping the surfaces of moons in the Solar System. Sesquinary impacts often form distinctive chains of craters, known as catenae, and can constitute a significant fraction of the total impactors on a moon's surface. Previous studies have looked at the process of sesquinary cratering on our Moon, as well as Ganymede, Io and Europa orbiting Jupiter, Tethys around Saturn, and Mars's moons Deimos and Phobos. In his paper, Michael Nayak, at the Air Force Research Laboratory, on Maui, Hawaii, focuses on Phobos.

Nayak used a computer model of primary impacts slamming into Phobos and tracked how the ejecta fragments orbited Mars before hitting the moon again. He focused on primary craters 1km across, which throw off ejecta streams travelling at up to 100m/s (360km/h). What he found from his calculations is that 85 per cent of the debris blasted off at escape velocity (around 40km/h on Phobos) eventually reaccretes back onto the moon's surface. Nayak says that this high percentage of returning material is because Phobos orbits so deeply within the gravitational field of Mars. Phobos orbits nearer to its planet than any other moon, so close, in fact, that it orbits faster than Mars spins. If you were to stand on the surface of Mars, you'd see Phobos rise in the west twice every Martian day.

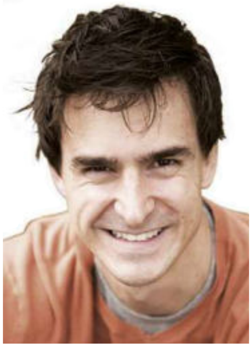
Phobos is gradually spiralling towards Mars, but Nayak calculates that the importance of sesquinary impacts on the moon has remained true for the past 25 million years. This means that the top 30cm of Phobos's regolith is mostly made up of ejecta that has subsequently reaccreted as sesquinary impactors. In essence, Phobos is mixing up its top surface by cycling it through orbit around Mars.

But even more interesting than that is the cascade effect triggered by this process. Some of the material

"85 per cent of the debris blasted off at escape velocity eventually reaccretes back onto Phobos's surface"

ejected by a sesquinary impact will be large enough that when it falls back down onto Phobos it triggers sesquinary impacts of its own. So a primary impact creates sesquinary craters that subsequently cause further sesquinary craters. The combination of Phobos's low gravity and tight orbit around Mars means that the moon is exceptionally good at stirring up its surface over time.

The fact that the surface of Phobos has become so thoroughly redistributed by this sesquinary impact process is crucial to appreciate when considering the geology and landscape of the moon, argues Nayak, especially for landing probes on Phobos in the future. It's also important to take the effects of sesquinary impacts into account when counting craters to estimate the age of regions of the moon's surface – these additional craters formed by the same primary impact would cause the surface to appear older than it really is.



LEWIS DARTNELL is an astrobiology researcher at the University of Westminster and the author of *The Knowledge: How to Rebuild our World from Scratch* (www.the-knowledge.org)

LEWIS DARTNELL was reading… *Sesquinary reimpacts dominate surface characteristics on Phobos* by Michael Nayak
Read it online at http://dx.doi.org/10.1016/j.icarus.2017.08.039

NEW

A new generation of observatories at unbeatable prices

The best newcomer - The Canadian manufacturer NexDome has brought a revolutionary new observatory dome design onto the market. The major feature is a **modular design** with two significant advantages - **low transport costs** and **straightforward construction which takes just a few hours**. Never before has a top observatory been so affordable!
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What's on

Our pick of the best events from around the UK

PICK OF THE MONTH

▲ Peter Davidson, the museum's senior curator of mineralogy, holds a Strathmore fragment

Down to Earth

National Museum of Scotland, Edinburgh, until 1 April 2018

At 1.15pm on 3 December 1917, a meteor flashed across the sky over central Scotland. It left a bright trail in its wake before breaking up in midair and landing around the towns of Blairgowrie and Coupar Angus. Three pieces landed in different fields, while a fourth crashed through the roof of a cottage. The event became known as the Strathmore Meteorite.

Now, 100 years later, the National Museum of Scotland has reunited the four fragments for the first time as part of a free exhibition called Down to Earth, detailing the history of the Strathmore Meteorite. The exhibit also includes the High Possil, Glenrothes and Perth meteorites, which represent the three other documented meteorite falls in Scotland between 1804 and 1998, as well as other meteorites from all over the world that are held in the National Museums Scotland's collections.

As well as the Strathmore Meteorite fragments, Down To Earth will bring together eyewitness accounts of their falls, along with documents and newspaper articles from the period, to tell the story of this early example of observational science.

Entry to the National Museum of Scotland is free. For more information on the display, visit the museum's website.
www.nms.ac.uk

BEHIND THE SCENES

THE SKY AT NIGHT IN JANUARY

BBC Four, **14 January,** 10pm (first repeat BBC Four, **18 January,** 7.30pm)*

Studying galaxy clusters like Abell 1835 might reveal the secrets of dark energy

THE INVISIBLE UNIVERSE

The Sky at Night explores the objects and phenomena that we think exist in the cosmos, but can't actually see. Taking on invisible matter, dark energy and the Oort Cloud, the team reveal the latest attempts to make the unseen visible, and how that could change our knowledge of the Universe.

**Check www.bbc.co.uk/skyatnight for subsequent repeat times*

Swansea Star Party

National Waterfront Museum, Swansea, 26 January, 6.30pm

Swansea Astronomical Society hosts a free evening of stargazing, open to the public and astronomers of all abilities. The event will include the chance to chat to seasoned Swansea stargazers, look at the night sky through telescopes and also hear a talk given by a member of the society. All Swansea Astronomical Society events are listed on their website.
www.classroominspace.org.uk

Caroline Herschel and Wernher von Braun

Room 411, Babbage Building, Plymouth University, 12 January, 7.30pm

German astronomer Caroline Herschel died on 9 January 1848 – 170 years ago. Plymouth Astronomical Society member Sheila Evans discusses Herschel's life and legacy, and she's joined by Dr Mike McCulloch of the University of Plymouth, who'll explore the work of rocket engineer Wernher von Braun (pictured). Free for members and £2 for non-members.
www.plymouthastro.btck.co.uk

Messaging to Extraterrestrial Intelligencies

Room 6.41, Royal College Building, Strathclyde University, 18 January, 7.30pm

How do we search for extraterrestrials? Should we send a signal to alert alien civilisations of our presence? Some say that this could be dangerous, as aliens may be ill-disposed to us. In this free talk for the Astronomical Society of Glasgow, Dr Alan Penny of the University of St Andrews argues that this objection is flawed and discusses the work of METI International, a group conducting research on this topic.
www.theasg.org.uk

MORE LISTINGS ONLINE

Visit our website at **www.skyatnightmagazine.com/whats-on** for the full list of this month's events from around the country.

To ensure that your talks, observing evenings and star parties are included, please submit your event by filling in the submission form at the bottom of the page.

GREAT IMAGES IN NASA, ISTOCK, SWANSEA ASTRONOMICAL SOCIETY, NATIONAL MUSEUMS SCOTLAND, X-RAY: NASA/CXC/UNIV. OF ALABAMA/A. MORANDI ET AL; OPTICAL: SDSS, NASA/STSCI

A PASSION FOR SPACE

with **Maggie Aderin-Pocock**

The Sky at Night presenter is blown away by her first aurora – much like the particles that cause them

The past few years I have spent working on *The Sky at Night* have been a privilege and it has led to some incredible opportunities: reporting on the descent of the Philae lander onto Comet 67P; being present at NASA as New Horizons flew past Pluto, and discussing some of the first images that the probe returned; and, this year, I was able to fulfil a childhood dream of seeing the Northern Lights.

A breathtaking auroral displays dances over the snow in Tromsø, Norway

ISTOCK/JOHN HEMMINGSEN

We looked into a number of options to hunt down the aurora borealis. They can be seen from northern Scotland, but the probability of seeing them so far south is low. Flying north from Leeds on a dedicated 'aurora flight' was also considered, but in the end we settled on a visit to Tromsø, a Norwegian town high in the Arctic Circle amongst the fjords. With an 80 per cent chance of seeing the Northern Lights from there, it was definitely our best shot.

Aurorae were once simply thought to be caused by the flow of charged particles from the Sun – the solar wind – interacting with the Earth's magnetic field: as the particles spiralled down Earth's magnetic field lines, they ionised gases in the atmosphere causing them to glow, just like a neon tube. However, new research indicates that this cannot be the complete picture. Measurements of particle speeds show that they themselves do not have enough energy to generate the light that we see. Another source of energy is needed, something that kicks the gas particles into the Earth's atmosphere at high speed.

Snap change

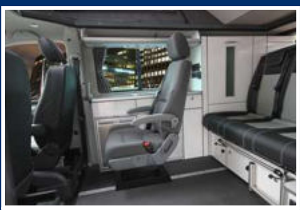
Scientists eventually realised that it was energy 'banked' into the electric and magnetic field of the solar wind itself. As the charged gas (plasma) shoots out of the Sun, it generates its own magnetic field, which travels to Earth with the particles. As this hits Earth's own magnetic field, the two fields react with each other, compressing and pushing and twisting until – suddenly – the magnetic field lines themselves snap and reform. And in that snapping a flash of energy is released; it is this kick that speeds up the particles as they head down into Earth's atmosphere, and that fast, dynamic kick is enough to cause them to ionise the atmosphere.

The result is magnificent: I had expected shimmering bands of light filling the whole sky from the pictures I had seen, but what surprised me was the dynamic nature of the aurora's movement. Scintillations danced fast across the sky, sheets of light expanded like ink spreading on blotting paper. It was one of the most glorious astronomical phenomena I have seen to date and it brought to life the movement of the solar wind. I had known it was there, but to see it displayed in a flurry of light was truly amazing.

Even with our better understanding of the phenomena the aurora is still throwing up mysteries. Quite why it forms into regular patterns remains hard to explain, and there's also a phenomena known as 'Steve', in which a column of light is produced, the causes of which are still being investigated. It's good to know that there are plenty of reasons for me to try and see them again sometime! S

Maggie Aderin-Pocock co-presents *The Sky at Night* and *CBeebies Stargazing*

Explore the Galaxy in Comfort and Style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JON CULSHAW'S

EXOPLANET EXCURSIONS

Jon visits a system that contains the first exomoon ever to be discovered

It's a phrase evocative of *The Last of the Mohicans*: 'the first of the exomoons'. But that's what is believed to have been discovered around a star similar to our Sun. Four thousand lightyears away in the constellation of Cygnus lies Kepler-1625, a yellow star with a radius 80 per cent larger than the Sun but only eight per cent more mass. You'd need a large telescope to observe it from Earth with its apparent magnitude of +14.0.

On this visit I'm steering the Perihelion to Kepler-1625b, a gas giant within the star's habitable zone. This world is about the size of Jupiter and completes a single orbit in 287 days at a distance of 0.81 AU.

This gas giant's moon is a giant in its own right – on a scale similar to Neptune – and it's likely not to have originally formed here, but instead been captured into its present orbit.

It's amazing to see this system through only my eyes: the sight of these planetary bodies together in the habitable zone of their parent star is one of great richness. I'm impatient to observe more closely at the earliest opportunity.

Adjusting my ship's gravitational balance to withstand the fairly hefty forces on this Neptune-sized Moon means I can follow a steady course over the surface at a relatively low altitude. The sky has a familiar blue hue in the moon's rather thick outer atmosphere and there are the most intriguing cloud formations that trace curved paths similar to DNA strands.

Close up, these formations are reminiscent of Earth's cumulus clouds. Their colours are deliciously odd too: brilliant, reflective white with patches of deep, vivid green running through. Is it possible these exomoon clouds could harbour some form of green algal life? Their luminescent silver accented with green shades makes for a bizarre view, like a holly leaf in November.

The vision that dominates the sky, however, is mighty Kepler-1625b. With contrasting raspberry-shaded bands laced with green streaks of its own, it's like observing Jupiter in another flavour.

This exomoon has moons of its own, as if to give the scene a Russian doll aspect. Asteroid satellites pepper the sky, each with a unique shape but all sharing the same crescent phase. Binoculars show up their features and impact marks. Many may have formed here; many will have been captured from elsewhere. I can count 20 or more such moon satellites, all scattered as if they've been hoarded by a great satellite collector.

Back on Earth, future observations of graceful Cygnus will hold greater fascination with the knowledge that the quirky and stunning features of Kepler-1625b's family exist within it.

Jon Culshaw is a comedian, impressionist and guest on *The Sky at Night*

MAIN ILLUSTRATION: MARK GARLICK, SPACECRAFT: PAUL WOOTTON, PHOTO: EMMA SAMMS

Interactive

EMAILS ◢ LETTERS ◢ TWEETS ◢ FACEBOOK

Email us at **inbox@skyatnightmagazine.com**

This month's top prize: four Philip's books

The 'Message of the Month' writer will receive four top titles courtesy of astronomy publisher Philips: Robin Scagell's *Complete Guide to Stargazing*, Sir Patrick Moore's *The Night Sky*, Robin Scagell and David Frydman's *Stargazing with Binoculars* and Heather Couper and Nigel Henbest's *2018 Stargazing*.

Tales from THE EYEPIECE

Stories and strange tales from the world of amateur astronomy by Jonathan Powell

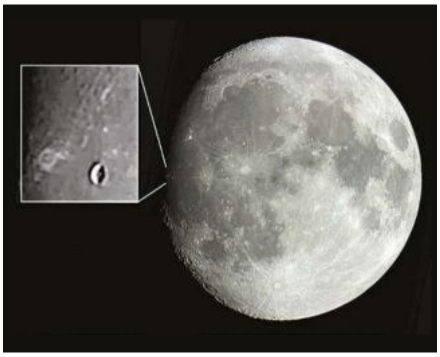
"For my astronomy O-level, I chose to study, sketch, and evaluate the Moon's Mare Crisium. Sitting on the northeast lunar limb, it's easily discernible with the naked eye. With the encouragement of the late Peter Grego, then head of the Lunar Section at the Junior Astronomical Society, I set about capturing the Sea of Crises. However, it wasn't my 2.4-inch telescope on wobbly wooden legs that thwarted me, nor was it the lack of an electric drive on said wobbly scope. No, it was the vast underestimation of the time involved. As the Moon waxed and waned, I was not prepared for how night after night, the most subtle of changes occurred, as the Sun's light captured the same landscape but from a different angle. Capturing these changes took time – many Moons, in fact."

Jonathan Powell is the astronomy correspondent for the South Wales Argus

MESSAGE OF THE MONTH

The lunar tadpole

Although not really a lunar observer, I was intrigued by the lunar 'swirl' discussed by Pete Lawrence on a recent episode of *The Sky at Night*. This mysterious feature, called Reiner Gamma, is one of the most visible lunar swirls and can be seen with most telescopes from Earth. It was originally thought to be a lunar highland, but then it was realised that it cast no shadow. On 1 November it was right on the terminator, so I got an image of it to observe this lack of shadow. You can see the shadows cast by the nearby Reiner crater, but indeed there are no shadows from Reiner Gamma (it's the white feature that looks a bit like a tadpole with its head to the left). These images were taken in Nailstone, near Hinckley, using my 'instantly available' 80mm f/5 refractor, which sits on an indoors upstairs windowsill, looking through the double glazing. I used a Bresser Mikrokular full HD camera. For the close-up image I used two stacked 2x Barlow lenses.



▲ **Roger's full disc shot of our Moon, with shadowless Gamma Reiner show inset**

Roger Samworth, via email

Fascinating, Roger. It's amazing that Reiner Gamma can be seen from Earth by virtue of its brightness alone! ***– Ed***

Classic conjunction

Here's my take on the 13 November conjunction of Venus and Jupiter. The images were taken from the water-meadows between Pyrford and Ripley, near Woking in Surrey. The first image shows the pair rising above the ruins of Newark Priory – one of the abbeys that Oliver Cromwell "knocked about a bit". The second was taken using my Williams Optics Megrez refractor but on a fixed mount – note the aircraft taking off from Gatwick photobombing the shot. The camera for both was Canon EOS 550D DSLR.

John Axtell, via email

What a great record of this memorable event, John. Thanks! ***– Ed***

▲ **Venus and Jupiter above Newark Priory (left) and close up with an interloping aircraft (right)**

SOCIETY in focus

▲ **Visitors explore the sky with society scopes**

Mansfield and Sutton Astronomical Society held its third open night of the season on 25 November. We had 194 visitors, supported by 26 society members. The centrepiece of our own Sherwood Observatory is our 24-inch Newtonian reflector, built by the founder members some 40 years ago. Visitors were able to view the Moon and its landscape of craters, mountain ranges and other features. Later we turned to the Orion Nebula, and were able to view the Trapezium Cluster too. Outside we had five telescopes and three pairs of binoculars trained on other delights.

All of our open nights are supported by a series of rolling talks throughout the evening, and the subject this time was 'Pictures of the Universe'. We also had radio astronomy equipment picking up meteor activity from the GRAVES transmitter in France, complemented by our deputy director exhibiting his collection of space rocks. Children enjoyed making craters (and a mess) in our 'crater creator' and, as people left, they were given a number of fact sheets, sky maps, and 2018 Moon phase posters.

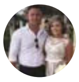
I would like to thank all those members who selflessly gave up their time and came along to make the event a resounding success. Without them, such events would not happen. More info about the society and activities can be found on our website.

Michael Lowe
Public Events Coordinator
www.sherwood-observatory.org.uk

Tweets

Steve Brown
Steve Brown @sjb_astro
• Nov 19
Composite image of the 1% lit #Moon, #Venus and #Jupiter rising on 17 Nov. Each shot 1 minute apart. #Astrophotography #astronomy #photography @VirtualAstro @skyatnightmag

Tweets



Scott Phillips
@ScottPhillips11 • Oct 11
First image of the Milky Way with my new Samyang 14mm f/2.8 lens #stars @spaceanswer @BBCStargazing @skyatnightmag

Carbon catastrophe

In your August issue, Ash Dove-Jay referred to space tourism in his article on private rocketry (page 43). The problem is that all rocket fuels produce masses of greenhouse gases, either in their manufacture (as in the case of liquid hydrogen) or in their burning (as in liquid hydrozene). Private rocket companies will certainly go for space tourism, but any individual considering a flight will engender a carbon footprint dwarfing the total of every other activity in their lifetime. The burgeoning private space industry cannot be left out of the green equation if we are ever to combat climate change.

Derek Smith, London

I quite agree, Derek. The environmental costs must be considered, especially if space tourism becomes affordable to greater numbers. By then though, there may be cleaner launch technologies available. ***– Ed***

No odd fish

I have always wanted a permanent dome for my scope but I don't have the space for one and it's a big cost. I thought it might interest you to see the solution to my problem: a fishing umbrella, which I have recently purchased. It makes the perfect low cost nylon dome and offers me and my scope protection from dew on the cold winter nights. It takes minutes to set up and cost about £30. I hope this helps those on a budget to enjoy their hobby.

Bill Ritter, Tewkesbury

What a great idea. An ingenious and cost-effective way of keeping off the dew, Bill! ***– Ed***

Bill's pop-up solution to a perennial problem

Meanwhile on FACEBOOK...

WE ASKED: What is your astronomy New Year's resolution for 2018?

Tony Moss
Just to enjoy stargazing.

Adrian Strand
To move to Arizona where I believe most nights of the year are clear!

Roy Alexander
Buy an amazing DSLR for nightscape photography. Can't decide on the Sony α7s or a Nikon 850 or similar Canon.

Sandra Grace
Mine is to find more time to focus on astronomy properly as haven't been able to do much this year.

Kayleigh Walker
As a beginner I want to gain better knowledge. I want to get a telescope and try some astrophotography.

Peter McCarthy
To make the skies darker.

William Wickham
To try and find a darker piece of sky.

Kari Brown
To raise above the clouds and keep trying.

Julia Wilson
To take the time to do more observing and gain more knowledge of a subject I am really enjoying learning about.

Al Higgs
To take images of comet Wirtanen and Jupiter and its moons for the first time through large binoculars.

Hotshots

This month's pick of your very best astrophotos

YOUR BONUS CONTENT

A gallery containing these and more of your stunning images

▲ The Small Magellanic Cloud and 47 Tucanae

MICHAEL SIDONIO, CANBERRA, AUSTRALIA, 23 OCTOBER 2017

Michael says: "The Small Magellanic Cloud (SMC) is one of the two most famous small satellite galaxies of the Milky Way and is visible with the naked eye even under moderately dark skies. Although it's 10 times closer to us, the second most mighty globular cluster in the sky, 47 Tucanae, sits right next to the SMC, making for a great pair to image. This was the first light image with my new scope and camera. I picked these targets because I could fit both into the same field of view."

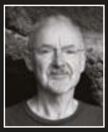
***BBC Sky at Night Magazine* says:** "This is one of those images that really puts across the enormity of the Universe. It's no small task to be able to capture the SMC with such clarity, but managing to include a crisp globular cluster is the icing on the cosmic cake."

Equipment: FLI ProLine PL16803 CCD camera, Takahashi FSQ-106EDX4 refractor.

About Michael: "I started in astronomy at the age of 15 after saving up for a 4.25-inch Tasco Newtonian. That year I also started dabbling in astrophotography using film and a 35mm SLR camera under the light-polluted skies of Newcastle, Australia. Now I have my own domed observatory under dark, rural skies."

◀ Moonset over the Angel

DAVID FROST, DERBYSHIRE, 20 OCTOBER 2017



David says: "The exposure was quite tricky as I wanted to try and get detail in the foreground below the Angel of the North, not totally blow out the Moon, and still make the stars visible. The exposure time was 25 seconds: there is slight trailing on the stars so it might have been better at 20 seconds, but I'm still very pleased with the result."

Equipment: Canon EOS M5 DSLR camera, 15-45mm lens.

▲ The Orion Nebula

SIMON HUDSON, LONDON, 29 OCTOBER 2017

Simon says: "I wanted to try an HaRGB image so I thought 'why not try something big and bright?' The Trapezium Cluster was difficult to control but I managed to fix it. Deep-sky imaging in a London suburb can be challenging!"

Equipment: QHY9M CCD cooled camera, Lacerta 200/800 Photo-Newton reflector, Celestron CGX equatorial mount.

▼ Orionids and the Orion Nebula

MICHAEL TEMPAN, LANCASHIRE, 26 OCTOBER 2017

Michael says: "A clear sky was forecast so I decided to take the opportunity to capture some images of the Orion Nebula. Some of my images picked up meteor trails, of which this was probably the clearest. There is a very obvious diagonal trail on the left hand side of the image, and also a faint trail in the middle."

Equipment: Canon EOS 80D DSLR camera, Sky-Watcher Star Adventurer, Sigma 105mm macro lens.

▲ NGC 281

GARY OPITZ, ROCHESTER, NEW YORK, US, 3 & 17 OCTOBER 2017

Gary says: "I created this false-colour image using two narrowband filters; hydrogen alpha and oxygen. I mapped these two filters to the red and blue colour channels respectively, then blending the data from the two filters together, I created a third, synthetic green channel."

Equipment: ZWO ASI1600MM camera, Telescope Engineering Company APO140ED refractor, Orion Atlas EQ-G mount.

◀ The Sun

AMIT SHARMA, LONDON, 5 NOVEMBER 2017

Amit says: "The weather forecast was clear only till 10am, meaning the Sun would not be visible from my usual spot, so had to drag my kit to the Thames bank where the Sun was hanging low over the Royal Observatory Greenwich, across the river. After an hour of processing, I am happy with how the camera captured fine details in an almost featureless disc."

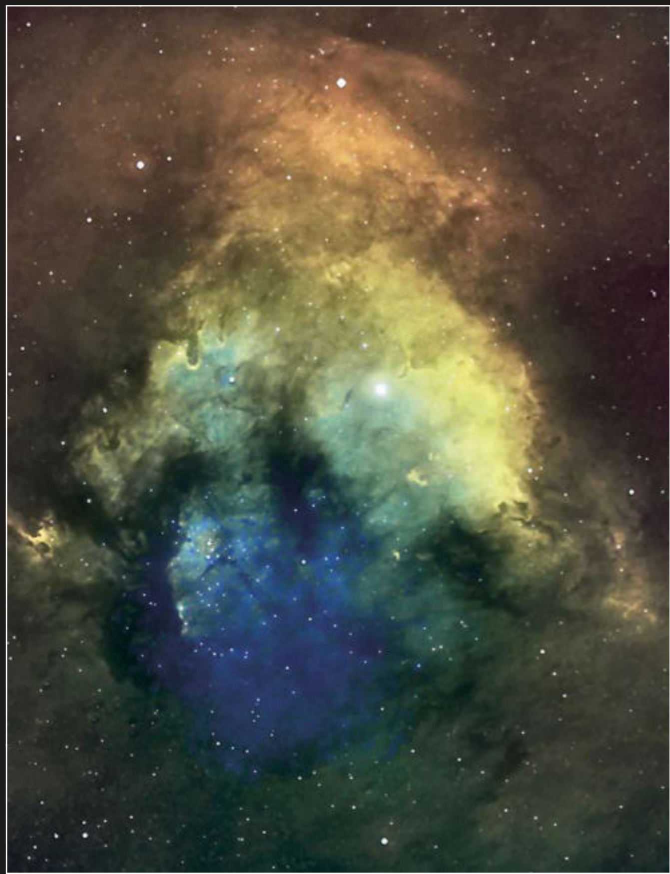
Equipment: Imaging Source DMK 41AU04.AS mono camera, TS-Optics Photoline 60ED refractor, iOptron SmartEQ equatorial mount.

▼ NGC 891

MARK WEBSTER, MANSFIELD, 29 OCTOBER 2017

Mark says: "Because of my work shift patterns, getting clear nights at home is a challenge. Last year I did no imaging because of poor conditions, so this year I switched back to one-shot-colour imaging. I'm really pleased with the results considering the seeing conditions."

Equipment: QHY10 colour CCD camera, Meade 10-inch Schmidt-Cassegrain, Sky-Watcher AZ EQ6-GT mount.



▲ NGC 7822

ROB LITTLE, CORBRIDGE, NORTHUMBERLAND, 22, 23 & 26 OCTOBER 2017

Rob says: "I am always on the lookout for new and interesting deep-sky objects to image. NGC 7822 was on my list and October is a good time to image this object from Corbridge. Thankfully the weather just allowed me to collect enough data."

Equipment: Atik 383L+ CCD camera, Takahashi FSQ-106 EDX4 apo refractor, Sky-Watcher NEQ6 Pro SynScan mount.

The winter constellation Orion forms one of the most famous and easily recognisable patterns in the night sky

CAPTURING THE HUNTER

The familiar winter constellation of Orion holds many surprises for imagers who want to delve a little deeper, says **Will Gater**

There are few constellations that grab the attention quite like that icon of the winter heavens, Orion. The glittering bright stars, the instantly recognisable 'belt' and the many glowing nebulae scattered within the Hunter's boundaries all make Orion a wonder to behold on a frosty, dark night. But the constellation is also a rich hunting ground for astrophotographers seeking captivating targets of many kinds. In this article we're going to explore some of the different ways Orion's splendours can be captured on camera, from a simple nightscape that conveys the naked-eye view to advanced CCD imaging techniques that can reveal the constellation's extraordinary deep-sky features. And hopefully, by the end of this piece, you'll agree with us that no matter how many times you catch sight of the Hunter, you'll always find something new to inspire you and test your astrophotography skils.

WILL GATER X 8

ABOUT THE WRITER
Will Gater is an astronomy journalist, author and presenter. Follow him on Twitter at @willgater or visit willgater.com

The Hunter in his element

Orion's position near the celestial equator makes it easy to incorporate some landscape into your shots

Silhouetted treetops, city skylines or mountain peaks help contextualise Orion's position

EXPERIENCE LEVEL Beginner to intermediate

WHAT YOU'LL NEED A DSLR or bridge camera and a sturdy photographic tripod. A wide kit lens (of the kind that comes with most DSLRs) will be perfectly sufficient. More experienced astrophotographers may also want to use a portable tracking mount to capture longer exposures.

There's something tremendously evocative about glimpsing the bright stars of Orion over a wintery landscape – or towards the end of the autumn months just as the nights start to get longer and colder – so in this project we're going to look at how to shoot a 'nightscape' that attempts to capture some of that magic.

STEP 1 Make a conceptual plan

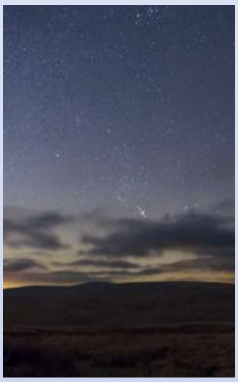
Thinking about the emotions you want to convey or elicit with your shot can help you to plan a powerful picture, and it'll inform every stage of the photographic process. For example, if you wanted to evoke the harsh iciness of winter observing you might shoot Orion over an isolated, leafless tree in a barren landscape, andprocess in such as way as to create a hard contrast between land and sky.

STEP 2 Select your focal length or a prime lens

Once you've thought about what atmosphere you want to capture with your image, you can select the focal length you'll be shooting at. A typical kit lens set to around 24mm, or an equivalent prime lens, provides a wide field of view for Orion on a camera's sensor, allowing you to fit in the brighter central stars and the Hunter's fainter outlying 'arms'.

STEP 3 Focus the view

Next focus the view. Some cameras have a live preview function that can be zoomed onto a suitable star, giving you instant feedback as you make slight focusing adjustments. With Orion there's no shortage of bright stars that can be used for this. Repeat the process a few times – checking that the star is a small as possible – so you're certain the image is as sharp as it can be.



STEP 4 Compose with the landscape and sky conditions

To compose your nightscape you can take short, very-high ISO test exposures to show you the balance and positioning of foreground and sky, and any structures or landscape features in frame. Try to use the foreground – trees, buildings, etc – to lead the viewer's eye toward Orion. Sometimes clouds can be used as a framing device too, and thin cloud can even 'bloat' and enhance the colours of bright stars.

STEP 5 Set the exposure length, aperture and ISO

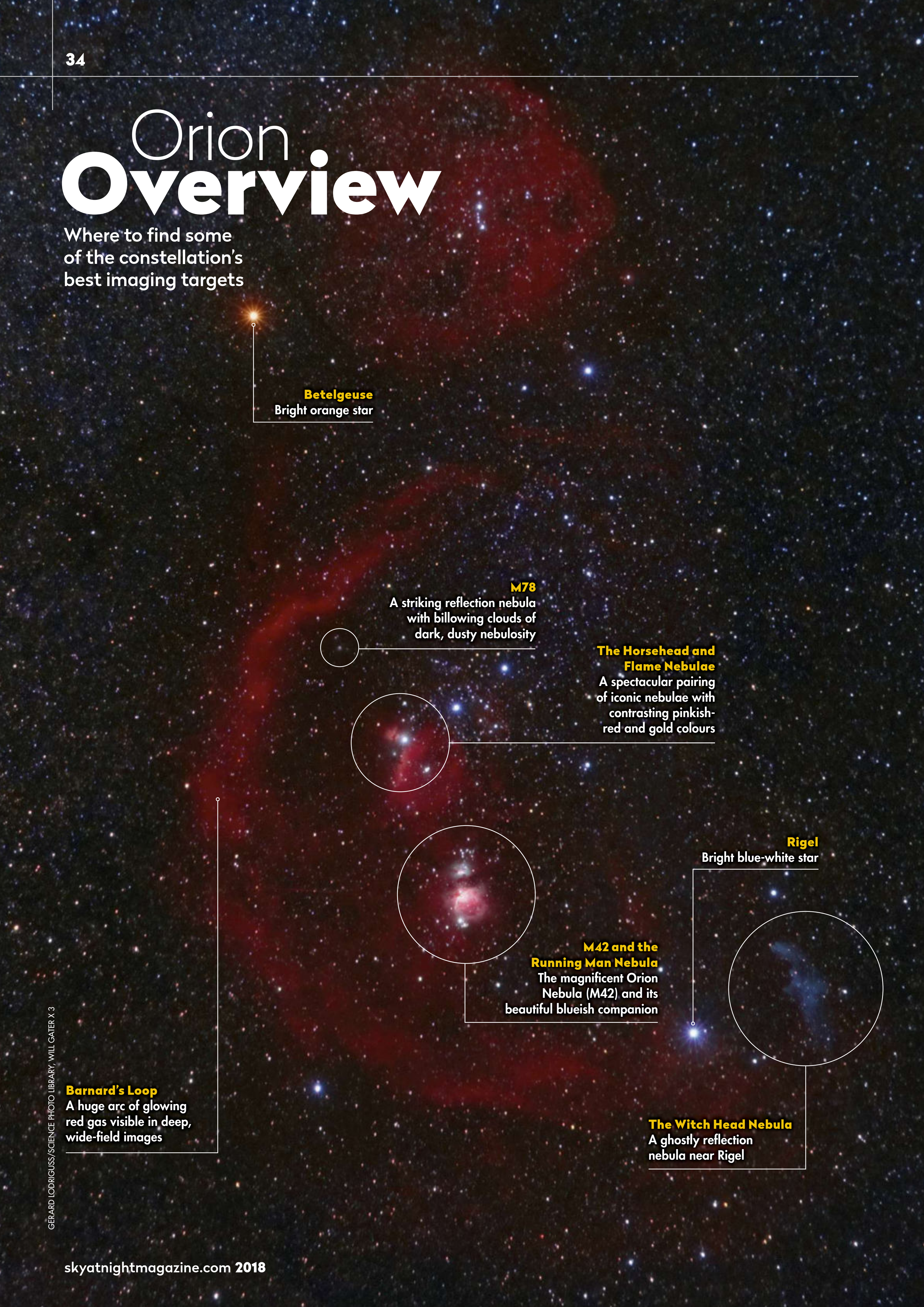
When shooting, keep the lens aperture wide open (lowest f-stop), though some lenses will perform better when reduced a few stops. Experiment with the ISO and exposure length until you're happy with the look. You may need to use an exposure that very slightly trails the stars in order to define the foreground.

STEP 6 Process your image

When processing nightscapes, reducing the noise in the image and bringing out foreground detail are the main challenges; as long as you shoot in RAW format, modern image-processing software is well-equipped to handle these tasks. In Photoshop or GIMP you can correct the colour balance, and use the 'Curves' tool to bring out star fields and improve overall contrast and definition. ▸

Orion Overview

Where to find some of the constellation's best imaging targets



GERARD LODRIGUSS/SCIENCE PHOTO LIBRARY, WILL GATER X 3

Far and WIDE

Reveal the hidden delights lurking within Orion with the help of long-exposure, wide-field imaging

EXPERIENCE LEVEL Intermediate
WHAT YOU'LL NEED A DSLR, a tracking mount and either a relatively long focal length camera lens (between 100 and 300mm focal length on a full-format DSLR) or a short focal length refractor. You could use a CCD camera, but the field of view produced by your setup will need to be at least 5° across or you'll need to mosaic.

One of the things that makes Orion so attractive for astrophotography is the diversity of deep-sky objects within its borders, from pinkish-red star forming regions to blue-tinted reflection nebulae.

The proximity of these targets to one another means that long-exposure wide-field imaging of Orion can produce some spectacular compositions. Not only do such wide-field images show the positions of objects such as the Orion and Horsehead Nebulae in relation to one another, but they can also reveal the rarely seen fainter surroundings of objects that are usually given the 'close-up' treatment, such as the aforementioned nebulae.

A DSLR with a long focal length lens and mounted on some form of equatorial tracking mount is probably the simplest setup with which to get started in wide-field imaging. Unlike most deep-sky imaging, wide-field deep-sky astrophotography generally doesn't require autoguiding, as it's possible to capture good data with unguided sub-exposures of just a minute or two.

With fast prime lenses and those relatively short exposure lengths, you may be surprised at how easily you can pick up some of Orion's most recognisable deep-sky objects. For the best results capture multiple sub-exposures (as well as dark frames and flat fields) and then calibrate and stack them, using software such as the free DeepSkyStacker, before final enhancements in your preferred image-processing software.

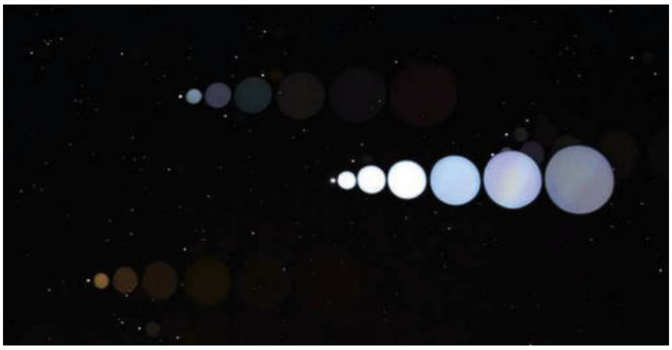

Wide-field imaging can reveal the Orion Nebula (M42) as hanging beneath Orion's Belt

Colourful captures

With the right setup you can show Orion is more than just white stars against a black background

EXPERIENCE LEVEL Beginner
WHAT YOU'LL NEED A basic DSLR or bridge camera fitted with a lens that allows manual focusing (some compact digital cameras will also work depending on the lens/focusing mechanism they use). You'll also need a photographic tripod and your camera will need to be able to take exposures of a few seconds.

The colour variation of Orion's bright stars is one of the most captivating things about the constellation, yet it can be tricky to capture these wonderful hues as the chromatic aberration in some camera lenses overwhelms the true star colour. One method for showing the tints of stars such as Betelgeuse, Rigel and W Orionis is to manually defocus the image. It's a technique that was made famous by the renowned astrophotographer David Malin many years ago. You can use this method with a wide lens (or a fast long lens) on a static tripod, as long as you use short exposures – a second or so in the case of a longer lens. All you do is frame the star (or constellation), defocus the lens a little by hand and capture an exposure, usually at a mid-to-high level ISO setting. In the two composite images below we focused on Betelgeuse and Rigel. We captured a number of exposures and in between each one we defocused the lens a bit more. Then we combined them into one frame using processing software. It's a very artificial composition, but it does give a flavour of one of the things that makes observing and imaging Orion special. ▸



▲ Combining progressively defocused images of Betelgeuse (left) and Rigel (right) will highlight the contrasting colours of Orion's brightest stars

Portrait of a stellar nursery

Capture the Orion Nebula's ethereal pink swirls of gas and dust that are giving birth to new stars

EXPERIENCE LEVEL Intermediate to advanced
WHAT YOU'LL NEED A small refractor or Newtonian telescope carried on a motorised tracking mount, plus a monochrome CCD camera (and a computer to control it) with a set of LRGB imaging filters and a filter wheel. For exposures of more than a few minutes it's also a good idea to use an autoguiding system alongside the above, though this is not absolutely necessary.

There are few greater tests of a deep-sky astrophotographer's skills than the magnificent Orion Nebula, M42. Among the many challenges it provides are the faint outer regions of the nebula that can be lost in processing, or simply not picked up at all during the imaging process, and its dazzlingly bright core that requires careful planning to capture. In the step-by-step guide below we've described the basic process of how to go about shooting M42 with the kind of setup you might typically have if you're starting out in CCD imaging – that is a monochrome CCD camera and a set of LRGB filters (luminance, red, green and blue) with which to make a full-colour image.

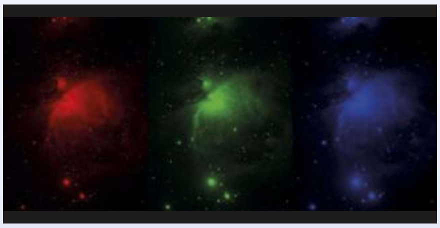

Capturing all the detail and colour of the Orion Nebula is a challange

STEP 1 Set up and polar align accurately

Once you've got your equipment set up, spend some time finessing the polar alignment of your mount. This is so you'll be able to get the longest unguided exposures your mount is capable of before the stars drift out of position – this is especially important if you're not using autoguiding equipment.

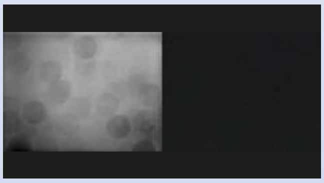
STEP 2 Capture different length luminance exposures

Use short, 'binned', test exposures to compose the image. Then take three groups of exposures through a clear luminance filter: short ones for M42's bright core, longer ones for the main body and, for the faint outer regions, as long as your unguided mount can manage without the stars 'wandering' (usually several minutes).



STEP 3 Get the RGB colour

When you've got around 10-15 sub-exposures for each of the three groups of luminance data, you can move on to capturing the colour data through red, green and blue filters. Capture at least 10-15 images per colour channel – aim for an exposure length similar to your shots of the main body of M42 with the luminance filter.

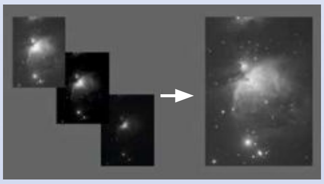


STEP 4 Take dark frames and flat fields

After capturing each 'LRGB' channel, carefully stretch a clean white pillowcase or t-shirt over the scope aperture (without touching the lens) and illuminate it with a torch before taking an image. This is a flat field, which records image artefacts such as vignetting and dust on the optics. Also take a set of dark frames if the data from your CCD needs them.

STEP 5 Stack and calibrate the data

You should now have six sets of sub-exposures: three luminance groups of varying exposure length and one for each of the RGB channels. Load them into your preferred astronomical image-processing software (for example, DeepSkyStacker) and use the flat fields and dark frames to calibrate them before stacking those calibrated sets into six images.



STEP 6 Combine the three luminance images

Bring the three luminance images into layers-based image processing software, such as Photoshop or GIMP. With each image in a separate layer, erase the overexposed portion of the long-exposure image so that the 'main-body' exposure shows through – do the same for the main body layer so the core shows clearly. Merge the layers.

STEP 7 Add the colour and make final processing adjustments

Next, place your red, green and blue filtered images in their respective colour 'channel' in a new image file. Copy the resulting full-colour image, as a separate layer, into the luminance file created in Step 6 and turn its blending mode to 'Colour'. Lastly make any final image tweaks to your taste. S

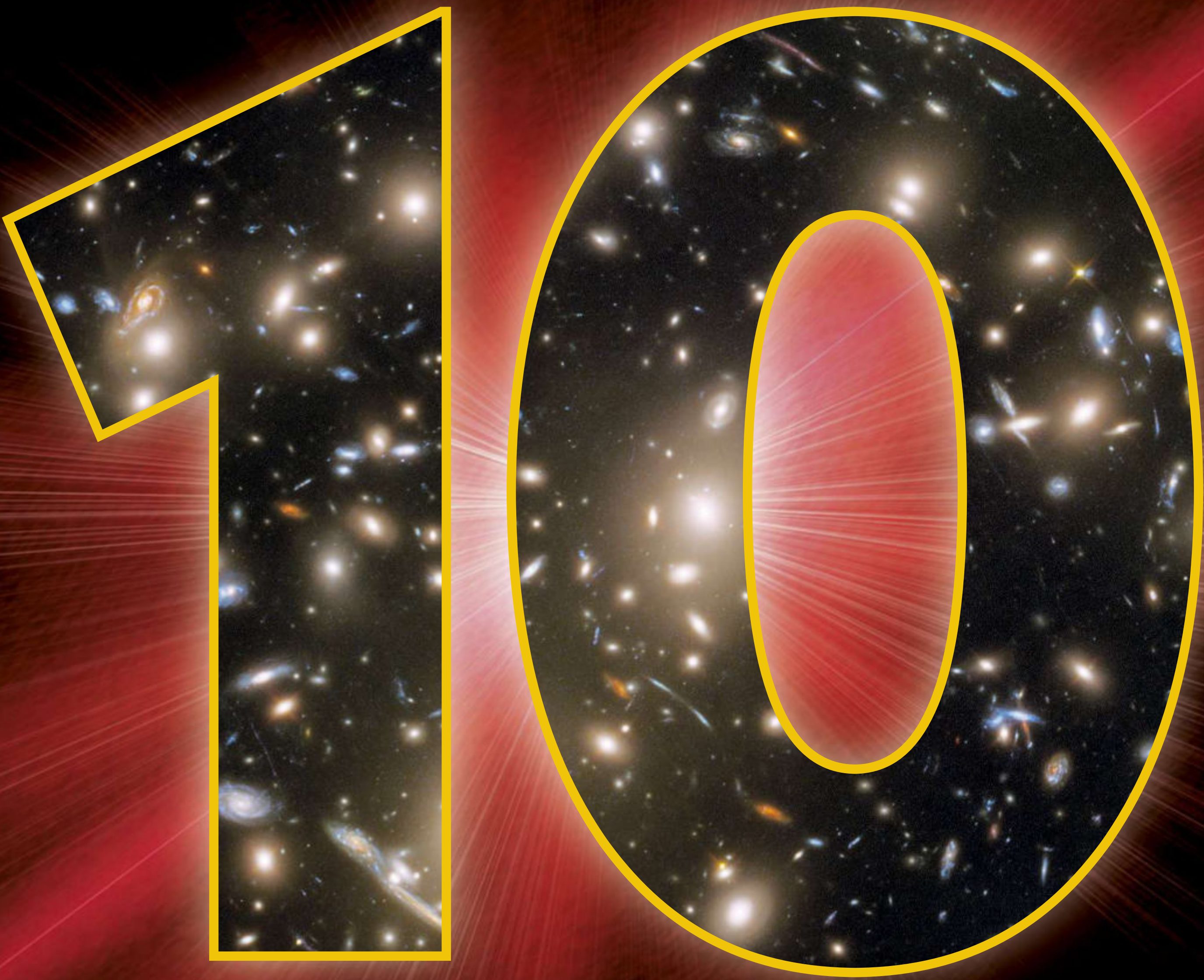
WILL GATER X 8

"Dave had just flown all the way from Alpha Centauri."

"Theakston's Best Bitter please," he asked the android behind the bar. Our hoverstools whooshed us to a table where our pints waited, golden as a Neptunian sunset. *"You know, they've been brewing this cask beer the same way for over 2,875 years,"* Dave said. *"Bet it still tastes just as good too,"* I replied. Dave was now in full flow. *"And they use the same mash tun from 1875. So every pint of cask Theakston's in the entire universe ever has come from just one mash tun, including everyone's in this bar now."* I looked around the Time Traveller's Arms. Rick the Robot was nursing his pint and busy snacking on iron-filing flavour crisps. In the corner sat Artus Minor and his wife Debbie from Whitby. And across the room the Andromeda twins were playing six dimensional dominoes. *"What you are witnessing, my friend,"* Dave explained, *"is intergalactic harmony on a grand scale."* His eyes were bright with belief. *"And it's all down to Theakstons and their 2,875 year old mash tun!"* Honestly, I really do sometimes wonder what planet Dave is on.

"Boy, was he thirsty."

THE TALK OF THE PUB.



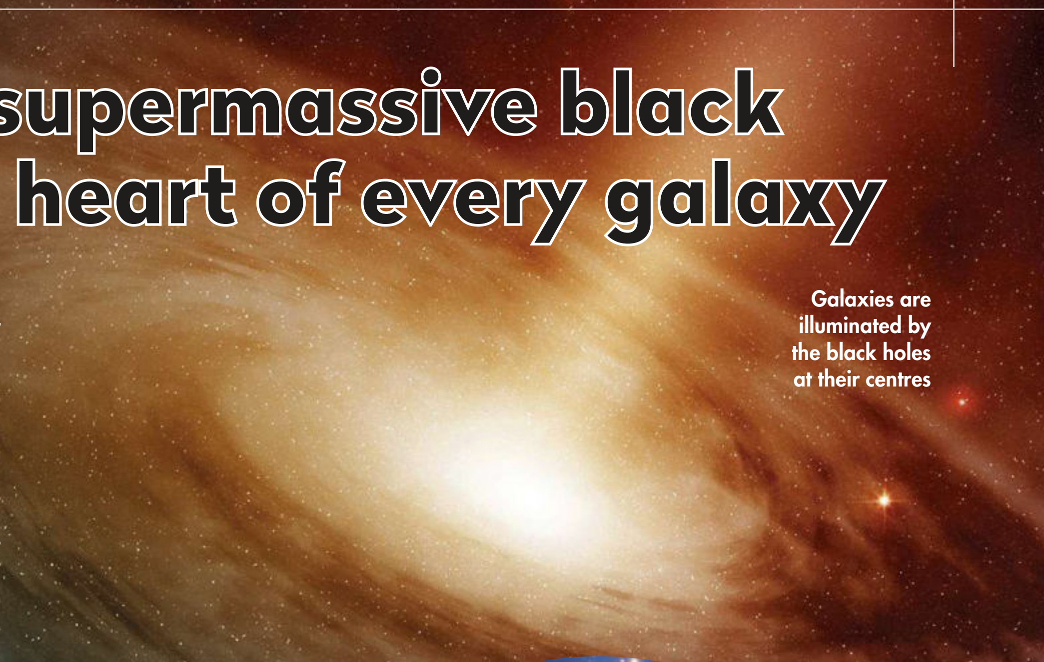
10 ASTOUNDING SPACE DISCOVERIES

The Universe is a mindboggling place, says Marcus Chown, as he guides us through some of its strangest aspects

The Universe is astounding. Put it this way: all of its ordinary matter, all the particles that make us and everything we can see only make up four per cent of its matter. We only discovered the Universe's major mass component, the thing that makes up 70 per cent of it, in 1998. We call it dark energy – although nobody has the slightest idea what exactly it is. "The Universe", to paraphrase the British biologist JBS Haldane, "is not stranger than we imagine. It is stranger than we can imagine." In celebration of this joyful fact, here are 10 of the most astounding space discoveries of recent times.

ABOUT THE WRITER
Marcus Chown is a radio astronomer turned author. His latest book, *The Ascent of Gravity*, is out now.

There is a supermassive black hole in the heart of every galaxy

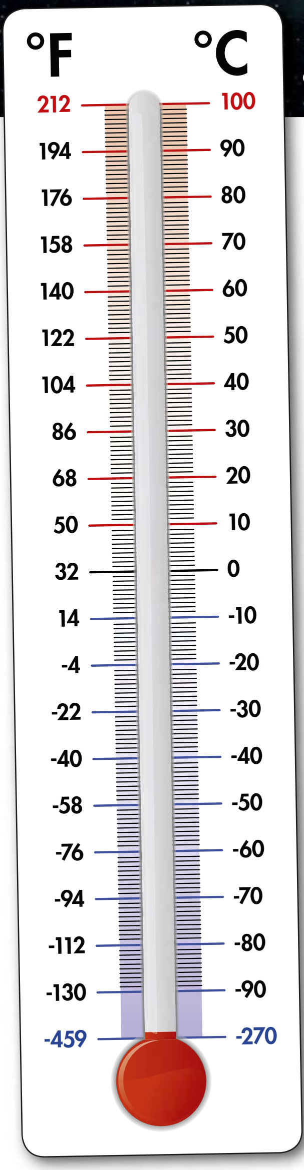


Active galaxies often pump out 100 times more light than a normal galaxy. With the discovery in 1963 of quasars, it was clear that the light comes not from stars but from a central region smaller than the Solar System. The only conceivable energy source is matter heated to incandescence as its swirls down onto a giant black hole up to 50 billion times the mass of the Sun.

In the 1990s, NASA's Hubble Space Telescope found that, although active galaxies account for only about one per cent of galaxies, supermassive black holes are no anomaly. Almost every galaxy, including our Milky Way, contains one, but starved of a food supply, most have switched off.

What are supermassive black holes doing in the hearts of galaxies? Were they the seeds around which galaxies congealed? Or did new-born galaxies spawn them? These remain some of the biggest unsolved questions in astrophysics.

Galaxies are illuminated by the black holes at their centres



◄ An expanding Universe would suggest an uneven temperature, and yet…

The Universe has the same temperature everywhere

The heat of the Big Bang fireball was bottled up in the Universe. It had nowhere to go, so it is still around us today. The weird thing is that its temperature – 2.725°C above absolute zero (–270°C), the lowest temperature possible – is essentially the same everywhere. Yet, if we imagine cosmic expansion running backwards, like a movie in reverse, we find that parts of the Universe that are on opposite sides of the sky today were not in contact when the fireball of radiation broke free of matter. In other words, there has been insufficient time for heat to travel between them and the temperature to equalise since the Universe's birth.

Astronomers fix this by maintaining that early on, the Universe was much smaller than expected, so heat got around easily. To get from this smaller size to its present size, the Universe had to go through an initial burst of superfast expansion, known as inflation.

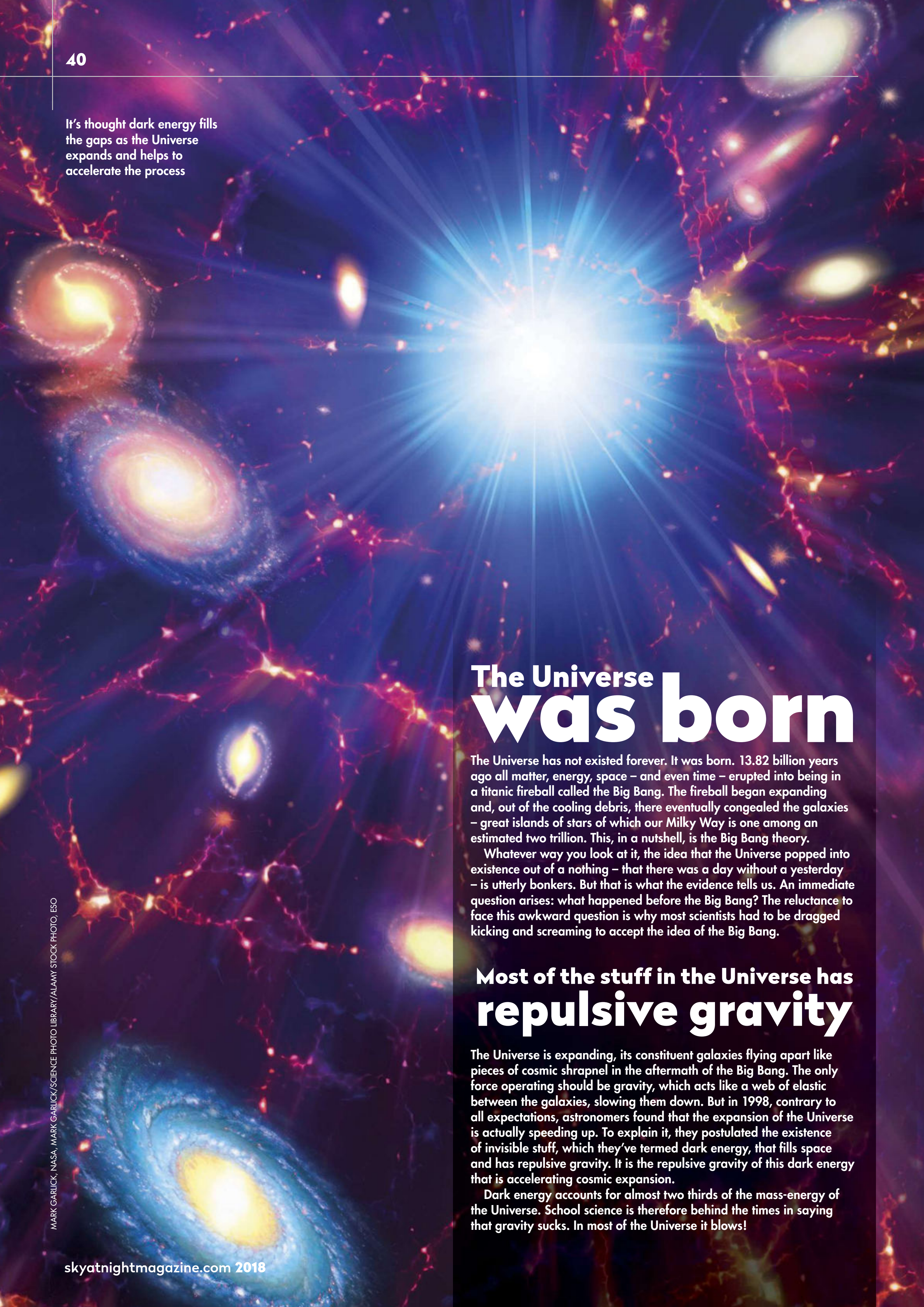
The ring superimposed on this Hubble image is a representation of the dark matter thought to be causing the distortions in the galaxy cluster

95% of the Universe is invisible

There is a discovery so amazing that it has yet to trickle into the consciousness of most working scientists: everything science has been studying these past 350 years is but a minor contaminant of the Universe. Only about 4.9 per cent of the mass-energy of the Universe is atoms – the kind of stuff you, me, the stars and galaxies are made of (and, of that, only half has been spotted with telescopes).

About 26.8 per cent of cosmic mass-energy is invisible, dark matter, revealed because it tugs with its gravity on the visible stuff. Candidates for what makes up dark matter include hitherto unknown subatomic particles and black holes made in the Big Bang. But, in addition to dark matter, there is dark energy, accounting for 68.3 per cent of the mass-energy of the Universe. It's invisible, fills all of space and is accelerating cosmic expansion. And our best theory – quantum theory – overestimates its energy density by a factor of one followed by 120 zeroes! ►

ISTOCK X 3, NASA/ESA/HUBBLE/HST FRONTIER FIELDS, NASA/ESA AND M.J JEE (JOHN HOPKINS UNIVERSITY)



It's thought dark energy fills the gaps as the Universe expands and helps to accelerate the process

The Universe was born

The Universe has not existed forever. It was born. 13.82 billion years ago all matter, energy, space – and even time – erupted into being in a titanic fireball called the Big Bang. The fireball began expanding and, out of the cooling debris, there eventually congealed the galaxies – great islands of stars of which our Milky Way is one among an estimated two trillion. This, in a nutshell, is the Big Bang theory.

Whatever way you look at it, the idea that the Universe popped into existence out of a nothing – that there was a day without a yesterday – is utterly bonkers. But that is what the evidence tells us. An immediate question arises: what happened before the Big Bang? The reluctance to face this awkward question is why most scientists had to be dragged kicking and screaming to accept the idea of the Big Bang.

Most of the stuff in the Universe has repulsive gravity

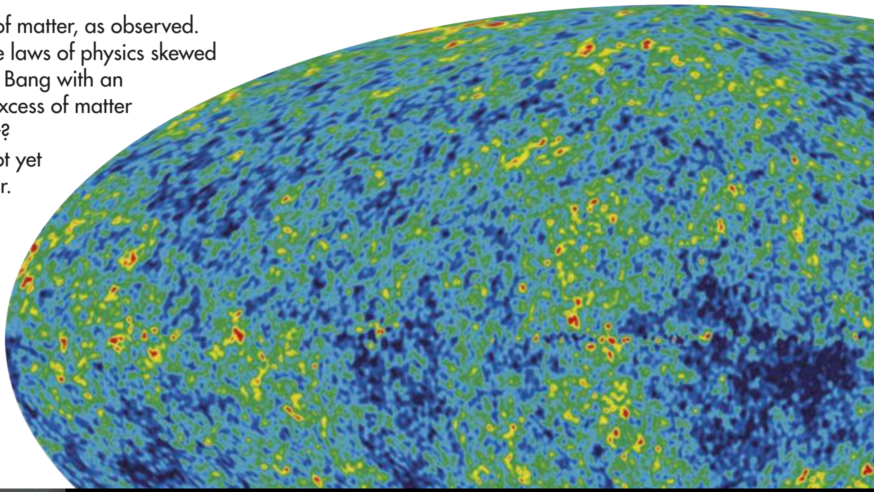
The Universe is expanding, its constituent galaxies flying apart like pieces of cosmic shrapnel in the aftermath of the Big Bang. The only force operating should be gravity, which acts like a web of elastic between the galaxies, slowing them down. But in 1998, contrary to all expectations, astronomers found that the expansion of the Universe is actually speeding up. To explain it, they postulated the existence of invisible stuff, which they've termed dark energy, that fills space and has repulsive gravity. It is the repulsive gravity of this dark energy that is accelerating cosmic expansion.

Dark energy accounts for almost two thirds of the mass-energy of the Universe. School science is therefore behind the times in saying that gravity sucks. In most of the Universe it blows!

The Universe contains no antimatter

Particles and antiparticles have opposite properties such as electric charge. The antiparticle of the negative electron, for instance, is the positive positron. Every process in physics creates equal amounts of matter and antimatter. So why is the Universe made of just matter instead of equal amounts of matter and antimatter?

A clue comes from the afterglow of the Big Bang, which contains about 10 billion photons for every particle of matter in the Universe. When a particle meets its antiparticle, it annihilates, ultimately into photons. So, at one time, the Universe must have contained 10 billion and one particles of matter for every 10 billion of antimatter. After an orgy of annihilation, 10 billion photons were left for every particle of matter, as observed. But why are the laws of physics skewed to favour a Big Bang with an ever-so-slight excess of matter over antimatter? Physicists do not yet have an answer.



► Today's cosmic background radiation hints at the state of the Universe prior to the Big Bang

Existing in different states simultaneously makes detecting neutrinos difficult

The Sun is producing only a third of the neutrinos expected

Hold up your thumb. 100 billion neutrinos are passing through your thumbnail every second. 8.5 minutes ago they were in the heart of the Sun. Solar neutrinos are a by-product of sunlight-generating nuclear reactions. When Ray Davis set out to detect them with 100,000 gallons of cleaning fluid down a mine in South Dakota, he expected to confirm the standard picture of the Sun. Instead, he found only a third of the expected neutrinos, something that was not only confirmed by later experiments but led to his Nobel Prize.

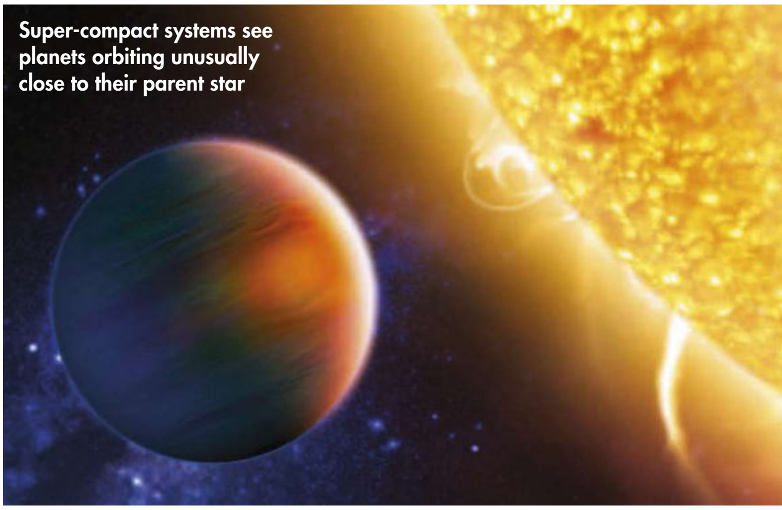
Neutrinos are ghostly subatomic particles existing in a weird quantum superposition – akin to an animal that is simultaneously a cow, a pig and a chicken. As they travel from the Sun, they flip between being an electron neutrino, a muon neutrino and a tau neutrino, which is why experiments sensitive to only one type pick up a third of the expected number.

Most planetary systems are very different from ours

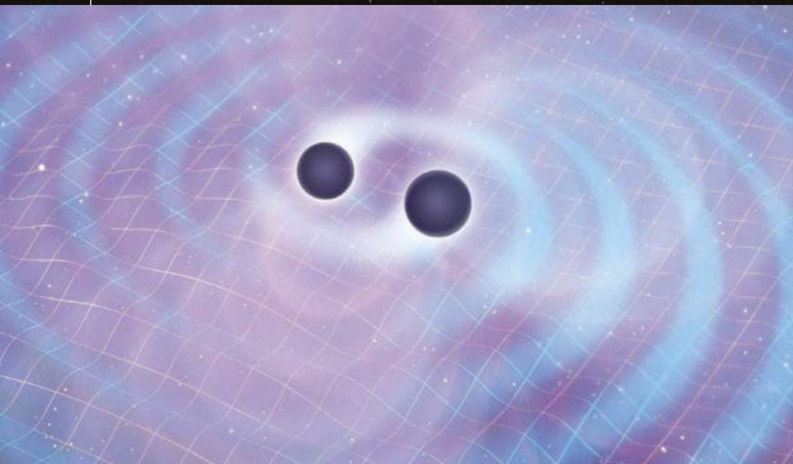
Scientists hate to invoke anything special about our situation in the Universe. 'Special' is improbable while 'typical' is probable. But the discovery of planets around other stars – at last count, more than 3,500 have been confirmed – has created a headache. None is like our own.

There are super-compact planetary systems in which all planets orbit closer to their parent star than Mercury, the innermost planet of the Solar System, does to the Sun. There are Jupiter-mass planets that must have migrated inward. There are planets in highly elliptical orbits, similar to those of comets. And there are planets that orbit the wrong way around their stars. Given that planets are believed to congeal from gas and dust swirling in the same direction around a new-born sun, this latter discovery is especially hard to explain.

As yet, nobody knows whether the unusualness of our Solar System has anything to do with the human race having arisen to notice it. ►



Super-compact systems see planets orbiting unusually close to their parent star



The energy released by the merger of two enormous black holes was enough to send ripples through space-time

The first gravitational waves came from a binary black hole system nobody predicted

On 14 September 2015, gravitational waves were detected on Earth for the first time. These ripples in the fabric of space-time – predicted by Einstein in 1916 – came from the merger of two black holes in a distant galaxy. Briefly, the power pumped out was 50 times greater than that of all the stars in the Universe combined. But this was not the only jaw-dropping aspect of the event. Each of the black holes was in the 30 solar mass range. Since a black hole is what's left after most of a star has blown into space as a supernova, the precursor stars must have weighed at least 300 solar masses. Such stars are incredibly rare today. But the two black holes could have been remnants of the very first generation of stars – thought to be huge – or even primordial black holes, born in the inferno of the Big Bang itself.

The vast expanse of space and time make detecting, let alone contacting, other civilisations extremely difficult

We appear to be alone

There are approximately 100,000,000,000,000,000,000,000 stars in the Universe. And probably more planets than stars. Yet in all this immensity there is only one place we know of where life exists: Earth.

Despite searches for intelligent signals, no sign of intelligent extraterrestrial life has been found. In fact, there is a good argument that if such life-forms exist out there, not only should we see signs of them but they should already have come here. "Where are they?" the physicist Enrico Fermi famously asked. Some astronomers think the answer is we are alone, that someone has to be the first.

But absence of evidence is not evidence of absence. It took three billion years for us to go from single cells to complex life, which suggests taking this step is hard. Technological civilisations like ours may be rare and their lifetimes short; we may have missed any others by millions or billions of years. The other alternative is that the nearest one may simply be too far away for us to detect.

MARK GARLICK, NASA

AI ASTRONOMY

As our planet's observatories and telescopes get more powerful, sifting through data becomes increasingly more time-consuming. Luckily, 'intelligent' computers may be able to help, writes **Alex Green**

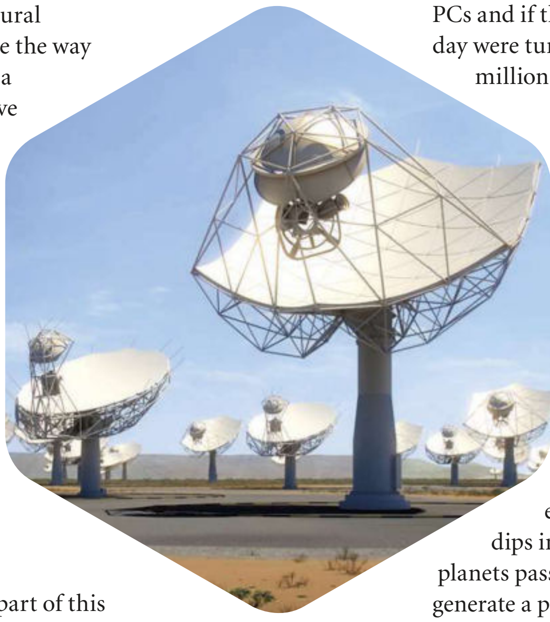
As the multitude of citizen science projects shows, the human brain is very good at recognising patterns in large sets of data. But artificial intelligence, or AI, is catching up. The ability of computer algorithms to find and identify specific features lying in vast datasets continues to improve.

The AIs that do this are called deep neural networks, or deep nets, and they replicate the way a human brain solves problems by using a collection of artificial neurons that receive and process information like those found in the human brain.

Deep nets also mimic the human brain in another key regard: they can learn. For example, given the right algorithm, a deep net can learn the photometric features of an exoplanet passing in front of its star by processing millions of light curves in a matter of seconds. As astronomers face an explosion in the amount of data generated from the next wave of telescopes that will soon to begin their observations, this ability will make AI a crucial tool for astronomers.

The Square Kilometre Array (SKA) is part of this next wave and promises to help usher in a new epoch for radio astronomy when it begins observations in 2020. The SKA's central computer will have processing power equivalent to one hundred million PCs and if the data it will be able to collect in a single day were turned into songs, it would take almost two million years to play back on an iPod.

"I was already studying the characterisation of exoplanet atmospheres so it was only natural to make the jump to exoplanet detection" – Kyle Pearson



▲ The Square Kilometre Array will generate too much data for a human to analyse in their lifetime

Dealing with big data

Exoplanet research is in a period known as the 'era of big data'. As ground- and space-based telescopes become more powerful and sensitive, the data they generate is increasing at an almost unmanageable rate, resulting in the need for more efficient ways to analyse it.

Currently one of the biggest datasets belongs to NASA's Kepler Space Telescope, which searches for exoplanets by measuring the minute dips in the brightness of 170,000 stars as planets pass in front of them. Kepler's observations generate a phenomenal amount of raw information, which, at the time of writing, has led to the discovery of 4,496 exoplanet candidates.

Kyle Pearson is an exoplanet hunter who has developed an AI to help search for worlds outside ▸

ISTOCK X 3, ESA/HUBBLE & NASA, ESO/L.CALCADA, ESO/B. TAFRESHI (TWANIGHT.ORG), ESO/M.-R. CIONI/VISTA MAGELLANIC CLOUD SURVEY, ESO, NASA/JPL-CALTECH/MSSS, KYLE PEARSON, © SKA ORGANISATION, © CARLO ENRICO PETRILLO (RIJKSUNIVERSITEIT GRONINGEN) X 2

From Google to galaxy clusters

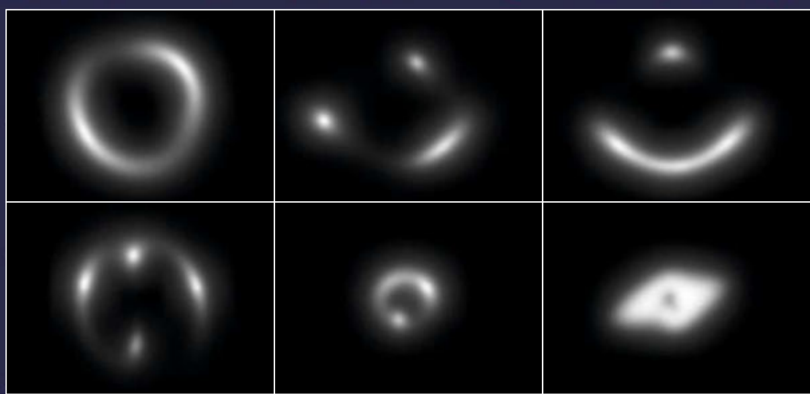
AI has numerous uses, from managing social media to detecting warps in space-time

AI algorithms used by Facebook and Google have been employed by astronomers to study a phenomenon that Albert Einstein proposed in his theory of general relativity over 100 years ago. In October 2017, a team of astronomers from the universities of Groningen, Naples and Bonn developed a method of detecting gravitational lenses using the same AI as the social network and search engine giants.

Gravitational lensing is an effect caused by an enormous mass warping space-time: massive objects such as galaxy clusters can be used as a sort of cosmic magnifying glass to observe more distant objects.

The AI algorithm the astronomers used is called a convolutional neural network and works on the same formulae employed by Google in 2017 to win a game of Go against the world's best human player. Facebook uses the same algorithms to compile data on the images that appear in its users' timelines.

The astronomers trained their AI using millions of images of gravitational lenses. Normally, human astronomers would examine all the images to look for potential candidates, but the AI was able to find 761 examples of gravitational lensing independently in a patch of sky 22 square degrees across – just over 0.5 per cent of the total area. The astronomers then narrowed down to 56 candidates awaiting confirmation through telescopic observation.



▲ Some of the fabricated images of gravitational lenses that the Groningen, Naples and Bonn astronomers used to train their neural network to recognise the phenomenon

▲ Three of the gravitational lenses discovered by the convolutional neural network

▸ our Solar System. During his first year studying Applied Physics at Northern Arizona University, Pearson was asked by his professor to apply what he'd learnt to his current research. "I was already studying the characterisation of exoplanet atmospheres," he says, "so it was only natural to make the jump to exoplanet detection." Pearson developed a deep net capable of scanning through data to detect exoplanets. It tries to learn what the potentially planet-signifying dips in star brightnesses should look like based on previous examples.

▲ Kepler will generate so much data that AI systems will be needed to analyse it in a practical amount of time

Teaching on test

One of the big advantages of deep nets is that they can be trained to identify very subtle features in large sets of data.

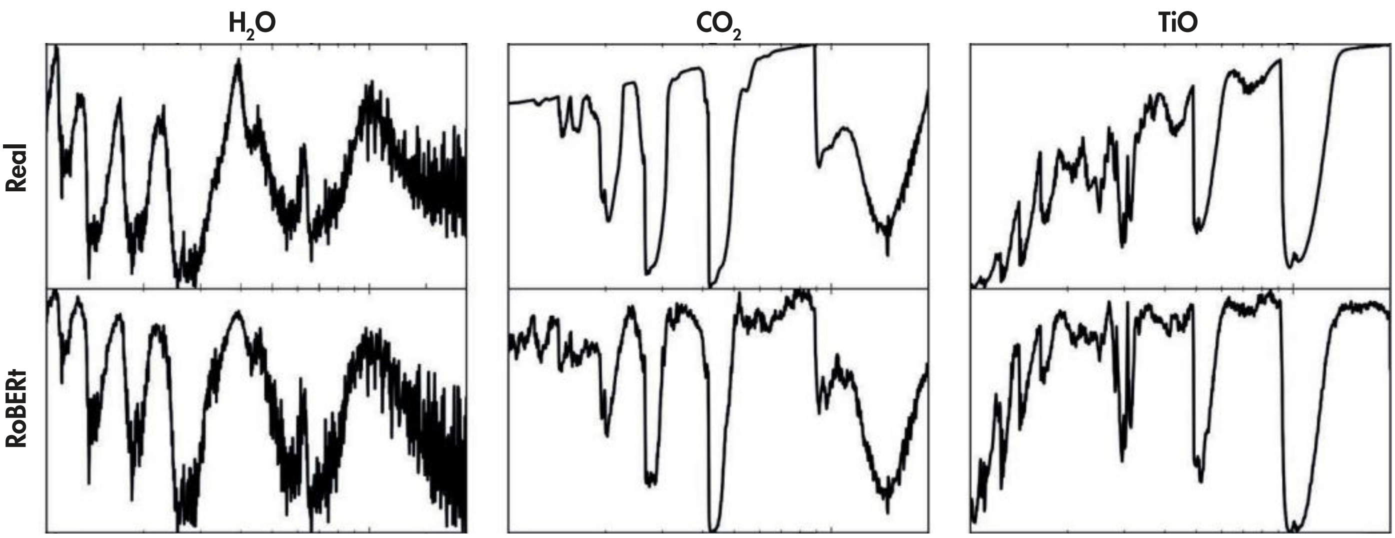
RobERt (Robotic Exoplanet Recognition) is a deep net created by Dr Ingo Waldmann and his team at University College London. Using over 85,000 simulated light curves from five classes of exoplanets, they 'taught' RobERt to recognise the presence of particular molecules and gases in exoplanets' atmospheres.

After the teaching was completed, RobERt was able to identify molecules such as water, carbon dioxide, ammonia and titanium oxide in light curves from real exoplanets with 99.7 per cent accuracy. It would take traditional atmospheric modelling approaches days to pick out this information from the masses of data collected by exoplanet observations. RobERt can do it much faster.

But to check RobERt had really 'learnt' how such compounds affect the light coming from exoplanets, Waldmann's team reversed

"One of the big advantages of deep nets is that they can be trained to identify very subtle features in large sets of data"

▲ Dr Ingo Waldmann stands next to the computer equipment that makes up the RobERt deep net, which has been trained to recognise exoplanet atmospheres



▲ Graphs showing how water (H_2O), carbon dioxide (CO_2) and titanium oxide (TiO) appear when detected in an exoplanet's atmosphere (Real) and in RoBERt's predictions. The similarity shows that RoBERT has the capability to identify these compounds independently

ESO, NASA AMES/JPL-CALTECH/T PYLE, INGO WALDMANN X 2, ISTOCK, NASA/JPL-CALTECH X 2, ESA/CC BY-SA 3.0 IGO, ESA/D.DUCROS/2013

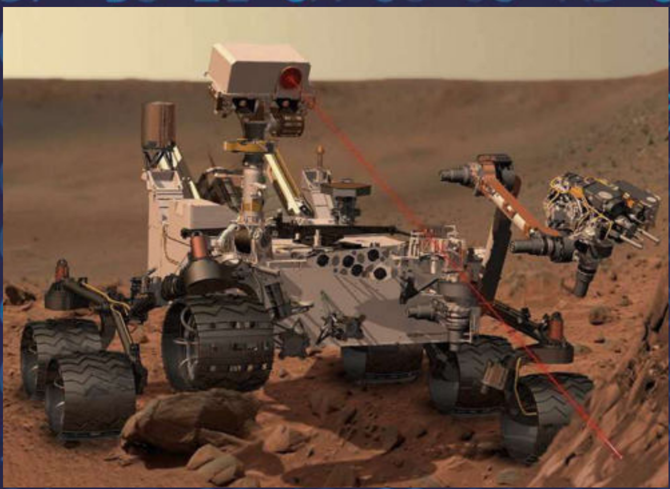
Intelligence on Mars

Intelligent rovers could pave the way for more efficient planetary exploration

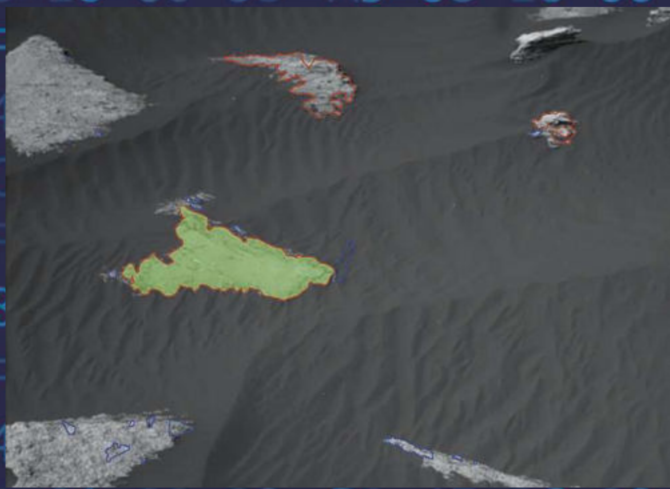
Artificial Intelligence on the Mars Curiosity rover has been helping it find targets for its ChemCam laser. The laser is used to vaporise small sections of rock or soil, so it can study the gas that burns off and send the data back to NASA scientists on Earth.

But rather than NASA's rover team having to select the targets for the ChemCam remotely, an AI system known as Autonomous Exploration for Gathering Increased Science (AEGIS) that's on board Curiosity takes care of the target selection process. This AI software gives Curiosity the ability to seek out interesting features for itself.

Each day, Mission Control programs a list of commands for the rover to execute based on the previous day's images and data. If those commands include travelling to a different location, the rover may reach its destination several hours before it is able to receive the instructions about its targets. AEGIS allows it to autonomously zap rocks and collect data for scientists to investigate later, allowing them to concentrate on other tasks. The software has proven so effective that it has been scheduled for use in NASA's upcoming rover mission Mars 2020.



▲ The AEGIS AI system on NASA's Curiosity Rover enables it to autonomously select targets for its ChemCam laser to analyse



▲ How AEGIS sees the Martian surface: blue targets are rejected, while red are retained. The top-ranked target is shaded green

the process and asked RobERt to predict the shape of light curves for various substances, which it did with impressive precision (see left).

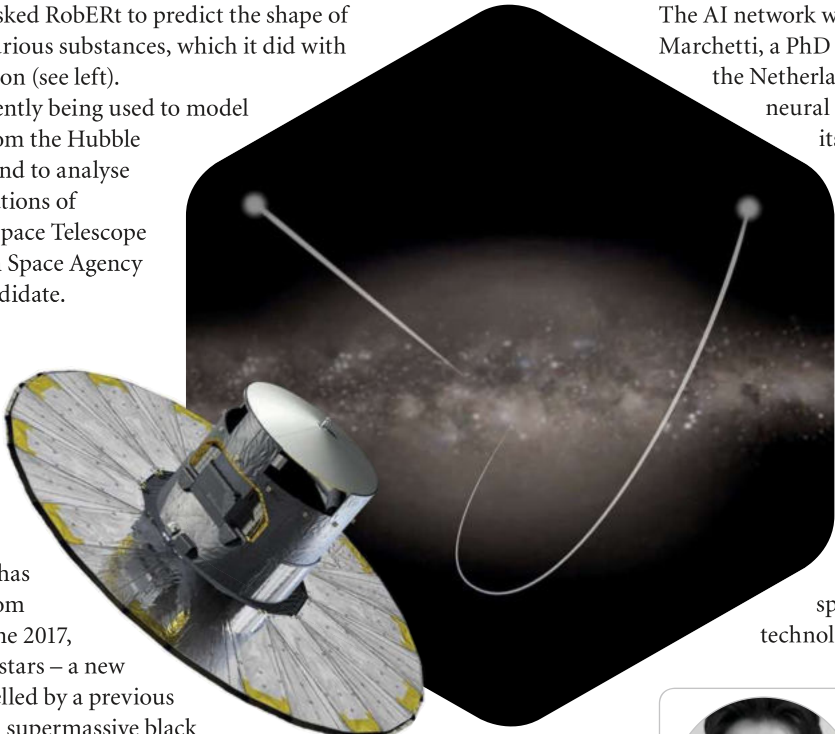
RobERt is currently being used to model exoplanet data from the Hubble Space Telescope and to analyse predicted observations of the James Webb Space Telescope and the European Space Agency Ariel mission candidate.

New stars

ESA's Gaia satellite, a space observatory designed to chart the biggest 3D map of the Universe to date, has also benefitted from AI analysis. In June 2017, six hypervelocity stars – a new class of star propelled by a previous interaction with a supermassive black hole – were spotted in Gaia's observations zipping from the centre of the Milky Way to its outer regions.

The stars were found with the help of an AI network that analysed the data Gaia gathered. The AI network was developed by Tommaso Marchetti, a PhD student at Leiden University in the Netherlands. "We chose to use an artificial neural network for two main reasons: its ability to learn highly nonlinear functions to identify interesting objects and to generalise input data not encountered during the training," Marchetti says.

One thing is for sure – the future of astronomy is data-rich. As our telescopes become more sensitive and powerful, the information that will be beamed back for analysis will be abundant. But whether it will be humans or computer algorithms that discover the next Earth-like exoplanet – or perhaps even our species' next home – only time and technology will tell.



▲ Two hypervelocity stars were discovered in Gaia observations with the help of an AI algorithm

ABOUT THE WRITER

Alex Green is a science writer based in Peterborough. His areas of expertise include black holes, astrobiology and space exploration.

Written by
PETE LAWRENCE
Pete Lawrence is an expert astronomer and astrophotograper, and a presenter of *The Sky at Night* on BBC Four.

THE SKY GUIDE January

January has two full Moons, the first being the perigee full Moon for 2018. The second is popularly known as a Blue Moon.

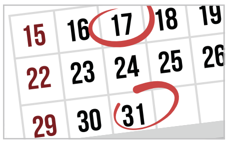
PLUS

Stephen Tonkin's
BINOCULAR TOUR
Turn to page 60 for six of this month's best binocular sights

DON'T MISS...

▷ Daylight lunar occultation of Regulus
▷ Comet C/2016 R2 PanSTARRS passing the Hyades
▷ Double shadow transit on Jupiter

PETE LAWRENCE



JANUARY **HIGHLIGHTS**

Your guide to the night sky this month

MONDAY 1

Mercury reaches greatest western elongation, appearing to be 22.7° from the Sun in the morning sky. See page 56.

TUESDAY 2

Tonight's moon is the perigee full Moon of 2018 – the largest and brightest of the year, but only by a small amount! See page 52.

Asteroid Flora reaches opposition today. See page 59.

WEDNESDAY 3 ▶

It may not feel like it in wintry Britain, but the Earth is at the closest point in its orbit to the Sun – a point known as its perihelion.

The Quadrantid meteor shower reaches its peak under unfavourable Moon conditions.

SUNDAY 7

The planets Jupiter and Mars appear just 13 arcminutes apart in the morning sky.

MONDAY 8 ▶

As the Moon is moving into the morning sky, this is a great time to start looking for the objects listed in this month's Deep-Sky Tour on page 62. This time we're looking at some interesting clusters and nebulae close to the eastern end of Orion's Belt.

WEDNESDAY 10

With no Moon in the early evening sky, this is a good time to pop outside with young astronomers and see whether you can get them to pick out the Celestial G, a giant pattern that runs through some of sky's brightest stars.

SUNDAY 14

The Orion Nebula, M42, is due south at 22:00 UT. There's no interference from the Moon, so this is a great time to get any new Christmas kit out and observe this amazingly rich deep-sky object. If you've never tried it before, why not have a go at photographing it too?

▸ See page 32 for more on imaging Orion and M42

MONDAY 15

Saturn and Mercury form a right-angled triangle with this morning's 2%-lit waning crescent Moon. View around 07:30 UT.

WEDNESDAY 17

A telescopic view of Jupiter this morning will show its outer Galilean moon, Callisto, passing close to Jupiter's northern limb.

FRIDAY 26 ▶

There's an opportunity to spot the lunar 'Jewelled Handle' this evening as the tops of the Jura mountains (which border the Sinus Iridum, or Bay of Rainbows) catch their first light after lunar dawn. See page 58.

WEDNESDAY 31

The second full Moon of the month. Such an event has become known as a Blue Moon. See page 52 to find out more.

PETE LAWRENCE X 7

FRIDAY 5

Look at Jupiter in the early hours and you will see it being transited by Ganymede and Europa. Io also reappears from occultation at 06:13 UT.

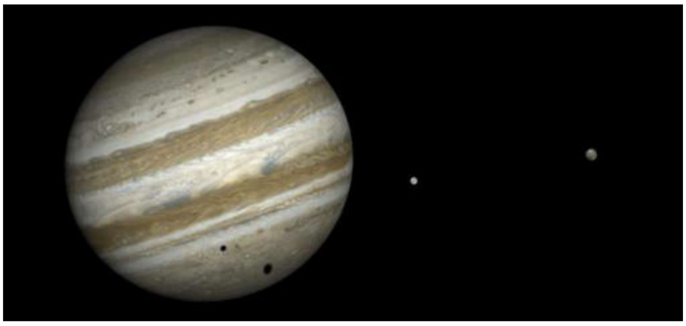
There's a daylight occultation of mag. +1.4 Regulus (Alpha (α) Leonis) by this morning's 85%-lit waning gibbous Moon.

SATURDAY 6

Comet C/2016 R2 PanSTARRS is close to the 'nose' of Taurus. This is marked by the star at the pointed end of the V-shaped Hyades open cluster, mag. +3.7 Hyadum I (Gamma (γ) Tauri). The comet is a faint mag. +13.2.

FRIDAY 12 ▶

Turn a telescope on Jupiter this morning to see a double shadow transit in progress. This event involves the shadows of Ganymede and Europa. See page 52 for timings.



THURSDAY 18

Our Star of the Month for January is amazing variable Mira, currently high in the sky, due south, as the sky darkens. At its faintest Mira can be a struggle to find with binoculars but right now it should be an easy naked-eye target. See page 59.

FRIDAY 19

The waxing Moon sets in the early evening, providing an opportunity to go hunting for the real Pole Star – our January challenge as set out on page 61.

FAMILY STARGAZING - 10 JAN

An asterism is a recognisable shape or pattern of stars making it easier to navigate around the night sky. Some are small and some big. The Celestial G is one of the largest. Make a game of pointing out the main stars as you join the dots to make the G. Start at Aldebaran tracing a line to Capella, Castor, Pollux and down to Procyon. Continue to Sirius, then up to Rigel before defining the horizontal stroke inside the G heading up to Bellatrix and then across to Betelgeuse. We've marked the G on our all sky chart on pages 54-55.
www.bbc.co.uk/cbeebies/shows/stargazing

NEED TO KNOW

The terms and symbols used in *The Sky Guide*

UNIVERSAL TIME (UT) AND BRITISH SUMMER TIME (BST)
Universal Time (UT) is the standard time used by astronomers around the world. British Summer Time (BST) is one hour ahead of UT.

RA (RIGHT ASCENSION) AND DEC. (DECLINATION)
These coordinates are the night sky's equivalent of longitude and latitude, describing where an object is on the celestial 'globe'.

FAMILY FRIENDLY
Objects marked with this icon are perfect for showing to children

NAKED EYE
Allow 20 minutes for your eyes to become dark-adapted

PHOTO OPPORTUNITY
Use a CCD, planetary camera or standard DSLR

BINOCULARS
10x50 recommended

SMALL/ MEDIUM SCOPE
Reflector/SCT under 6 inches, refractor under 4 inches

LARGE SCOPE
Reflector/SCT over 6 inches, refractor over 4 inches

GETTING STARTED IN ASTRONOMY

If you're new to astronomy, you'll find two essential reads on our website. Visit http://bit.ly/10_Lessons for our 10-step guide to getting started and http://bit.ly/First_Tel for advice on choosing a scope.

THE BIG THREE

The three top sights to observe or image this month

DON'T MISS

Daytime occultation of REGULUS

WHEN: 5 January from 07:30 UT

An interesting event occurs on the morning of 5 January, providing you a fantastic opportunity to see a night-time star during the day. At 07:30 UT, locate the 85%-lit waning gibbous Moon. Mag. +1.4 Regulus (Alpha (α) Leonis) will be 0.5° to the east of the Moon's eastern limb. With sunrise less than an hour away, the sky will be getting bright at this time. Keep watch using binoculars or a telescope at low magnification, as the Moon creeps ever closer toward the star.

Regulus is occulted by the Moon's bright limb just after 08:20 UT for observers in the centre of the UK. This time varies slightly with location, so we recommend that you start watching from around 08:10 UT. Reappearance is just before 09:16 UT in broad daylight. Despite this, the intense pin-point brilliance of Regulus should shine though if the sky is transparent. Start watching for the reappearance from 09:05 UT to ensure you don't miss it.

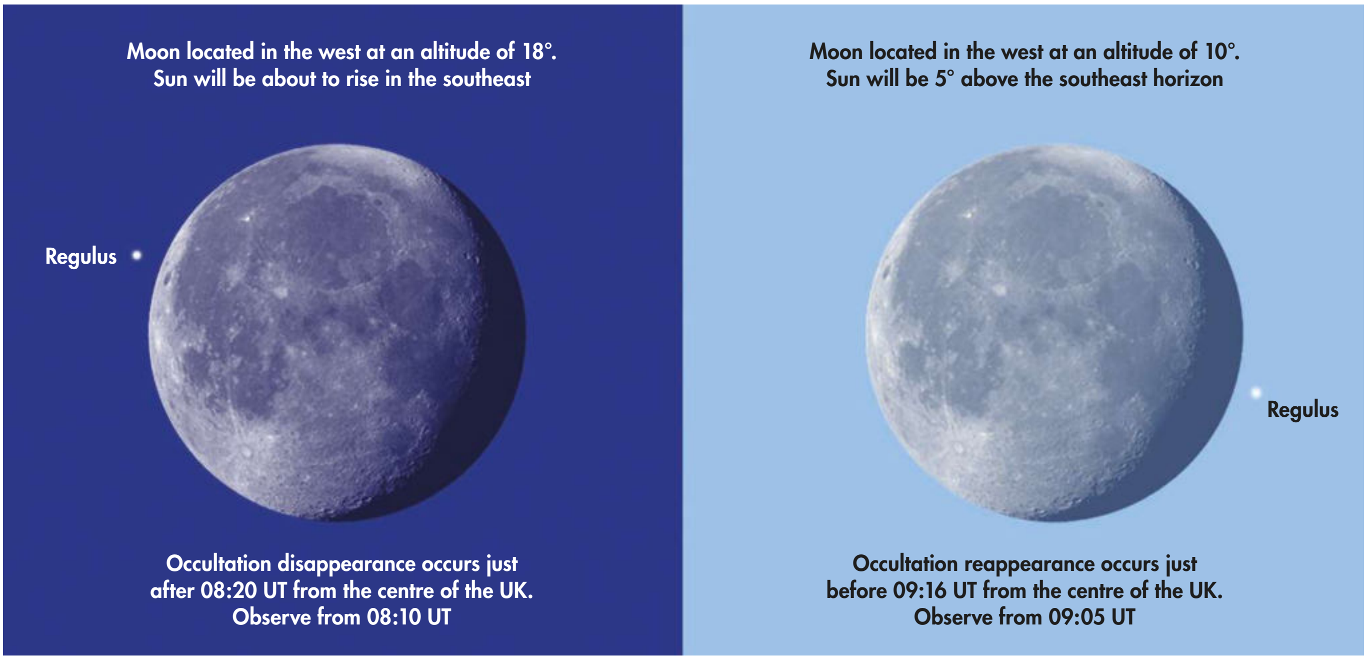
The full Moon on 2 January is the perigee full Moon of 2018. Perigee is the point in an elliptical orbit around the Earth when the distance between a body and our planet is at a minimum. The nature of the lunar orbit and phase cycle means that throughout the year, successive full Moons occur at positions that slowly move around the orbit. One of these will occur closer to the perigee point than the others. In 2018 this is the full Moon of 2 January. Being closer than the others, this full Moon will also appear slightly brighter and larger. Another consequence of lunar perigee is that the Moon's apparent speed across the sky is up to 6% faster than when it's at its farthest position from Earth, lunar apogee.

The full Moons either side of the perigee full Moon are only marginally smaller and dimmer. On 2 January, the Moon is full at 02:25 UT, and well positioned for optimum brightness and apparent size for the UK.

The term 'perigee full Moon' is often described in popular culture by the term 'supermoon'. This originally astrological term describes any full or new Moon which occurs within 90% of the perigee or apogee position.

A second full Moon occurs on 31 January, and technically it's another supermoon. The second full Moon in a month has become known as a 'Blue Moon', though originally this term referred to the third full Moon in an astronomical season with four of them. March offers a repeat performance with a full Moon on the 2nd and another on the 31st.

▲ Whatever term is used to describe it, a full Moon isn't an ideal time to point a telescope at our nearest neighbour because of its distinct lack of shadows

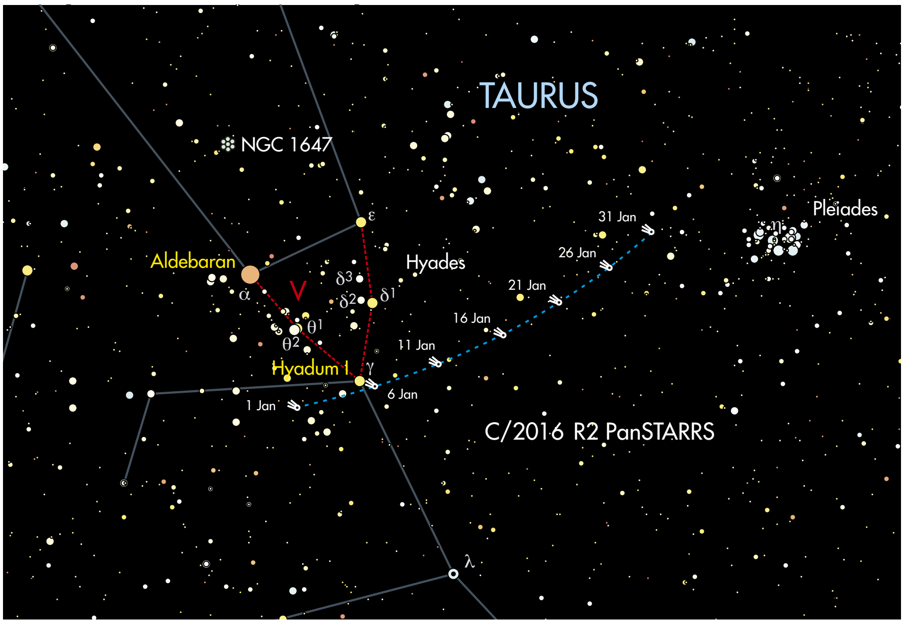


PETE LAWRENCE X 4

▲ The circumstances of Regulus and the Moon just before (left) and after (right) the occultation; times are given for the centre of the UK

Comet C/2016 R2 PanSTARRS clips the Bull's Nose

WHEN: Early evening from 5-21 January



▲ Comet C/2016 R2 PanSTARRS skims past the Hyades, then heads on towards the Pleiades

As comets go, C/2016 R2 PanSTARRS is a relatively faint one which will require a modest size of telescope to see. A smaller telescope fitted with a camera shouldn't have too much of an issue recording it as a mag. +13.2 glowing patch, slowly drifting against the background stars. It's the background stars that make C/2016 R2 PanSTARRS so approachable this month, because its track across the sky takes it right past the nose of Taurus, the Bull. Many descriptive parts of constellations can be tricky to identify if you're not used to them. Tracking down patterns representing Orion's club or the northern fish in Pisces can leave you scratching your head. In the case of Taurus, the head and nose couldn't be easier to find as both are represented by the V-shaped Hyades open cluster.

The V comes to a point at mag. +3.6 Hyadum I (Gamma (γ) Tauri) and it's this star that represents the Bull's nose.

At 00:00 UT on 1 January, the comet is located 1.75° southeast of Hyadum I and moving along a path that takes it ever closer to the star over the next few days. At 00:00 UT on 5 January, the comet is 18 arcminutes southwest of Hyadum I, while at 00:00 UT on 6 January it's located a similar distance to the west of it.

The issue on these dates will be the presence of a bright Moon to the east of Taurus. The best strategy is to observe early in the evening before the Moon rises. Fortunately the Hyades will be well positioned at this time and high in the sky towards the south.

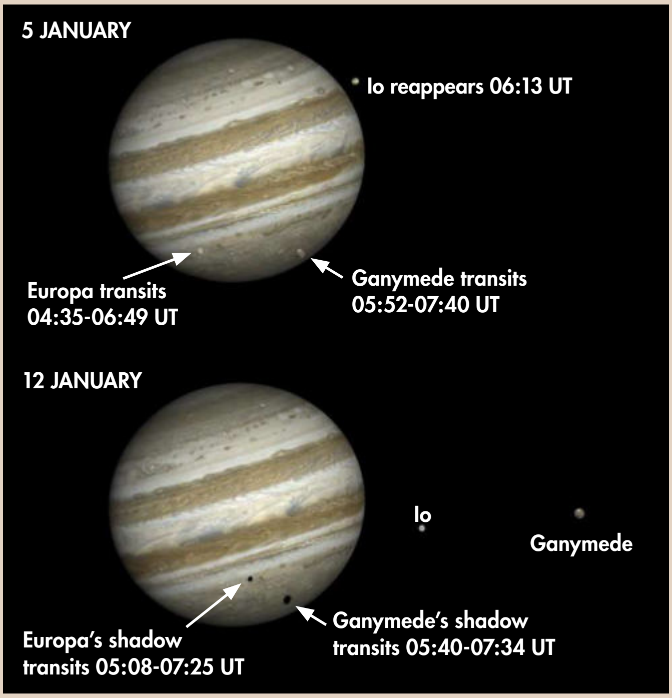
After the nose-scrape, C/2016 R2 PanSTARRS arcs up towards the north ending the month as a mag. +13.3 object 3° east of the Pleiades open cluster, M45.

A pair of double transits

WHEN: 5 January from 04:30 UT, 12 January from 05:05 UT

There are a number of interesting interactions between Jupiter and its four largest moons this month. Early in the morning on 5 January, Ganymede and Europa can be seen transiting Jupiter's disc. The double transit begins at 04:35 UT, with Europa passing across the planet's northeast limb. Europa's shadow will also be visible as a dark spot on Jupiter's atmosphere at this time, leaving the disc at 04:50 UT. Ganymede's transit begins at 05:52 UT. The double transit continues until Europa leaves the disc at 06:49 UT, as the sky brightens. Watch out for Io reappearing from behind Jupiter's southeast limb at 06:13 UT.

On 12 January, Europa's shadow can be seen passing onto Jupiter's disc at 05:08 UT, followed by Ganymede's giant shadow at 05:40 UT. Both moon shadows will be centrally placed at 06:30 UT. Europa itself begins to transit at 07:15 UT as the sky is starting to get bright before sunrise. Both shadows will be close to the northwest limb at this time. The double shadow transit ends at 07:25 UT as Europa's shadow passes off Jupiter's disc. Ganymede's shadow moves off immediately after this, leaving the disc completely by 07:34 UT. Sunrise is around 08:20 UT from the centre of the UK.



▲ Moon and shadow transit times for the two Jovian events in early January; in these illustrations, south is up

THE NORTHERN HEMISPHERE IN JANUARY

KEY TO STAR CHARTS

- Arcturus — STAR NAME
- PERSEUS — CONSTELLATION NAME
- GALAXY
- OPEN CLUSTER
- GLOBULAR CLUSTER
- PLANETARY NEBULA
- DIFFUSE NEBULOSITY
- DOUBLE STAR
- VARIABLE STAR
- THE MOON, SHOWING PHASE
- COMET TRACK
- ASTEROID TRACK
- STAR-HOPPING PATH
- METEOR RADIANT
- Circlet — ASTERISM
- PLANET
- QUASAR

STAR BRIGHTNESS:

- MAG. 0 & BRIGHTER
- MAG. +1
- MAG. +2
- MAG. +3
- MAG. +4 & FAINTER

- N E S W 5° — COMPASS AND FIELD OF VIEW
- MILKY WAY

CHART: PETE LAWRENCE

WHEN TO USE THIS CHART

1 JAN AT 00:00 UT
15 JAN AT 23:00 UT
31 JAN AT 22:00 UT

On other dates, stars will be in slightly different places due to Earth's orbital motion. Stars that cross the sky will set in the west four minutes earlier each night.

HOW TO USE THIS CHART

1. **HOLD THE CHART** so the direction you're facing is at the bottom.
2. **THE LOWER HALF** of the chart shows the sky ahead of you.
3. **THE CENTRE OF THE CHART** is the point directly over your head.

SUNRISE/SUNSET IN JANUARY*

DATE	SUNRISE	SUNSET
1 Jan 2018	08:25 UT	16:01 UT
11 Jan 2018	08:21 UT	16:15 UT
21 Jan 2018	08:11 UT	16:31 UT
31 Jan 2018	07:56 UT	16:50 UT

MOONRISE IN JANUARY*

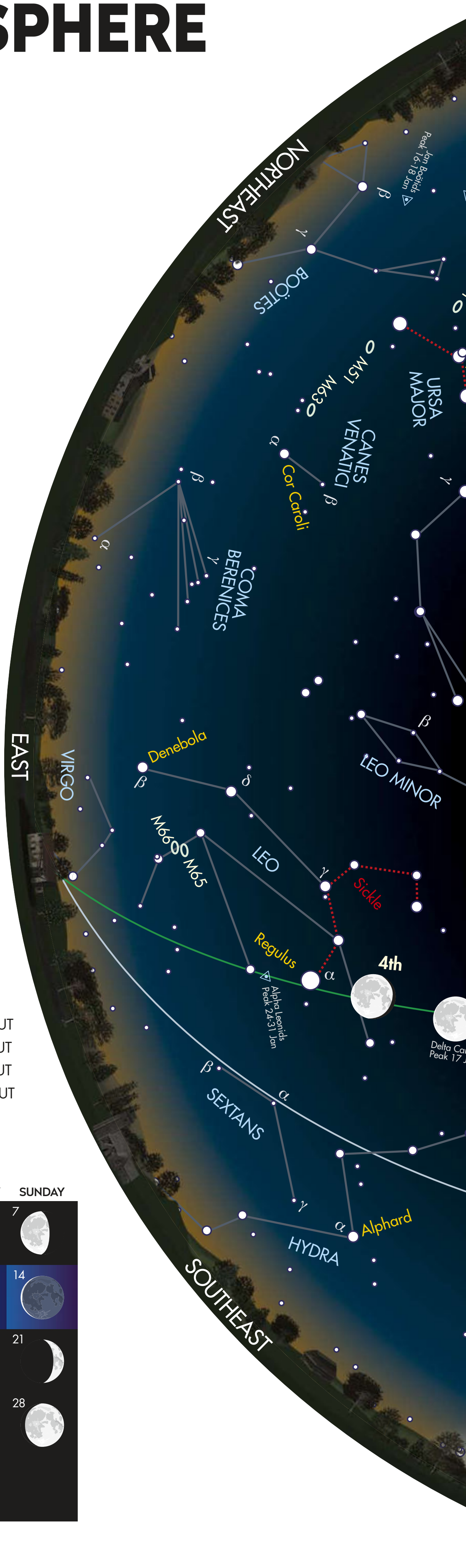
MOONRISE TIMES

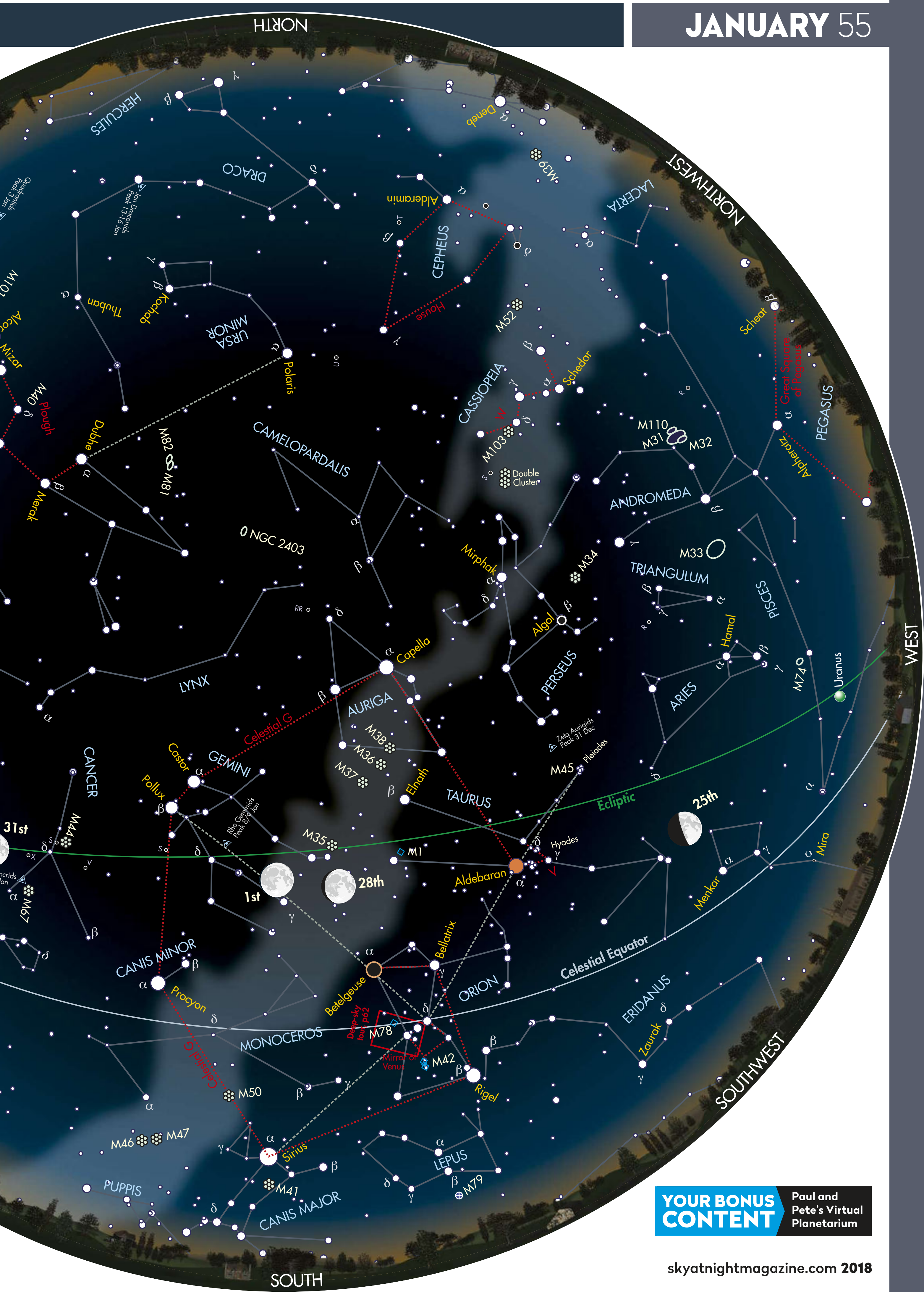
1 Jan 2018, 15:50 UT	17 Jan 2018, 08:21 UT
5 Jan 2018, 20:51 UT	21 Jan 2018, 10:12 UT
9 Jan 2018, 00:35 UT	25 Jan 2018, 11:41 UT
13 Jan 2018, 05:00 UT	29 Jan 2018, 14:30 UT

*Times correct for the centre of the UK

LUNAR PHASES IN JANUARY

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
1	2 FULL MOON	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17 NEW MOON	18	19	20	21
22	23	24	25	26	27	28
29	30	31 FULL MOON				




NORTH
SOUTH
WEST
NORTHWEST
SOUTHWEST
HERCULES
DRACO
Deneb
M39
LACERTA
Alderamin
CEPHEUS
Thuban
Kochab
URSA MINOR
Polaris
Mizar
Alcor
M101
M40
Plough
Dubhe
Merak
M82
M81
Garnet Star
M52
CASSIOPEIA
Schedar
Scheat
Great Square of Pegasus
PEGASUS
M103
Double Cluster
M110
M31
M32
ANDROMEDA
Alpheratz
CAMELOPARDALIS
NGC 2403
Mirphak
M34
M33
TRIANGULUM
PISCES
Algol
PERSEUS
Hamal
ARIES
M74
Uranus
Capella
AURIGA
LYNX
Quadrantids Peak 3 Jan
Jan Draconids Peak 13/16 Jan
Zeta Aurigids Peak 31 Dec
M45
Pleiades
Celestial G
M38
M36
M37
Elnath
TAURUS
CANCER
M44
GEMINI
Castor
Pollux
Rho Geminids Peak 8/9 Jan
Ecliptic
25th
31st
M35
M1
Hyades
Aldebaran
1st
28th
Mira
Menkar
M67
CANIS MINOR
Procyon
Bellatrix
Betelgeuse
ORION
Celestial Equator
ERIDANUS
Deep-sky tour p62
M78
Mirror of Venus
M42
Rigel
Zaurak
MONOCEROS
M50
M46
M47
Sirius
LEPUS
M79
M41
PUPPIS
CANIS MAJOR

THE PLANETS

PICK OF THE MONTH

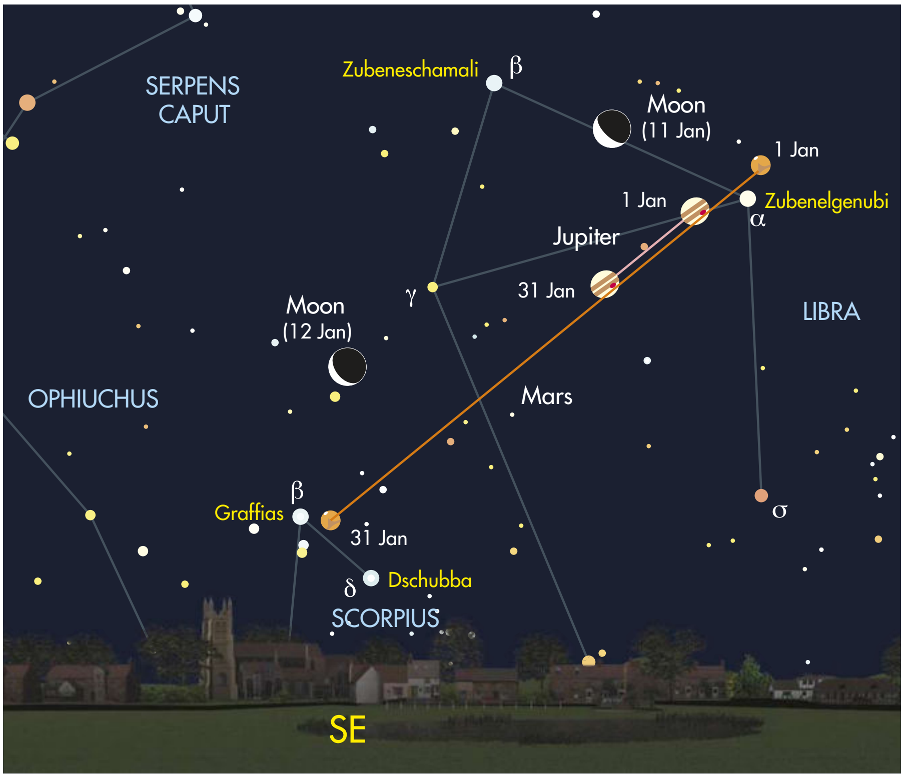
JUPITER

BEST TIME TO SEE: 31 January, 06:00 UT
ALTITUDE: 19°
LOCATION: Libra
DIRECTION: South-southeast
FEATURES: Complex atmosphere, Great Red Spot, Galilean moons
EQUIPMENT: 3-inch or larger scope

Jupiter is in Libra and a morning object. It fails to reach its peak altitude at the start of January, but just about manages it in the slowly brightening skies at the end of the month.

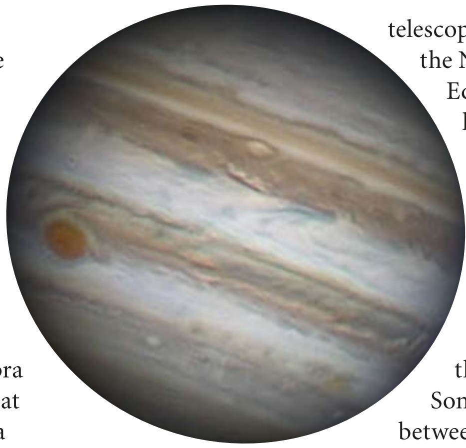
The start of 2018 sees Jupiter and Mars very close together in the morning sky. Jupiter shines at mag. –1.7 on 1 January with Mars significantly dimmer at mag. +1.5. Both planets appear close to mag. +2.8 Zubenelgenubi (Alpha (α) Librae) on New Year's morning.

The real close encounter, however, occurs on the mornings of 6 and 7 January. On 6 January, Mars appears 24 arcminutes southwest of Jupiter. If you can catch them soon after they have risen on 7 January – say from around 04:00 UT – they will appear around 13 arcminutes apart. This should present a good opportunity to photograph both worlds through a telescope, catching orange Mars and Jupiter, together with its Galilean moons, in the same frame. On the morning of 7 January, Europa and Io are located just east of Jupiter, with Ganymede and Callisto much farther away to the west of the planet.



▲ Jupiter and Mars in January; stars shown correct relative to horizon for 04:00 UT on the 31st

A waning crescent Moon joins the scene on the morning of 11 January. On this date the 28%-lit lunar crescent sits to the north of both planets. At the end of January Jupiter will appear more centrally postioned within Libra and slightly brighter at mag. –1.8. Through a telescope its oblate disc currently appears 35 arcseconds across. A small telescope will show both the North and South Equatorial Belts, located either side of the planet's equator. With concentration, a 4-inch telescope will show the planet's most famous feature, the Great Red Spot. Some good interactions between Jupiter and its moons will be visible this month and the best of these are listed on pages 50 and 52.

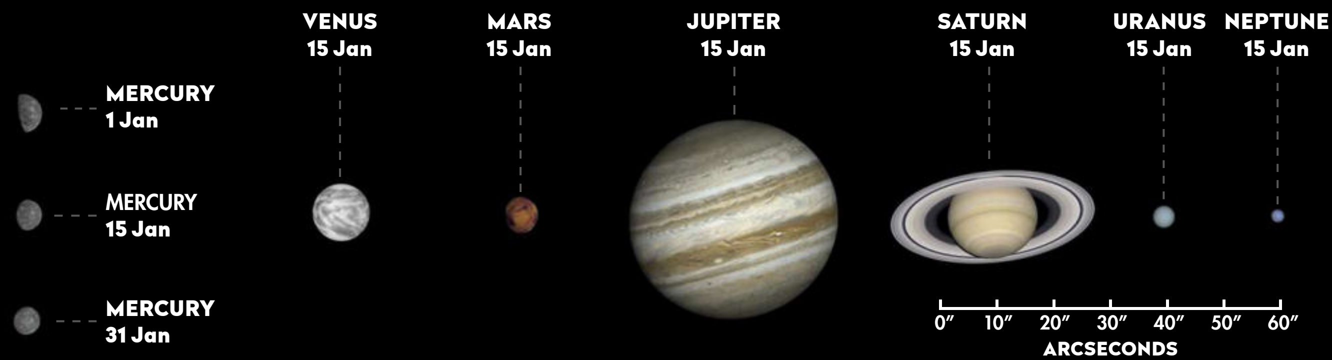


▲ The Great Red Spot is Jupiter's most famous feature and an easy target

PETE LAWRENCE X 3

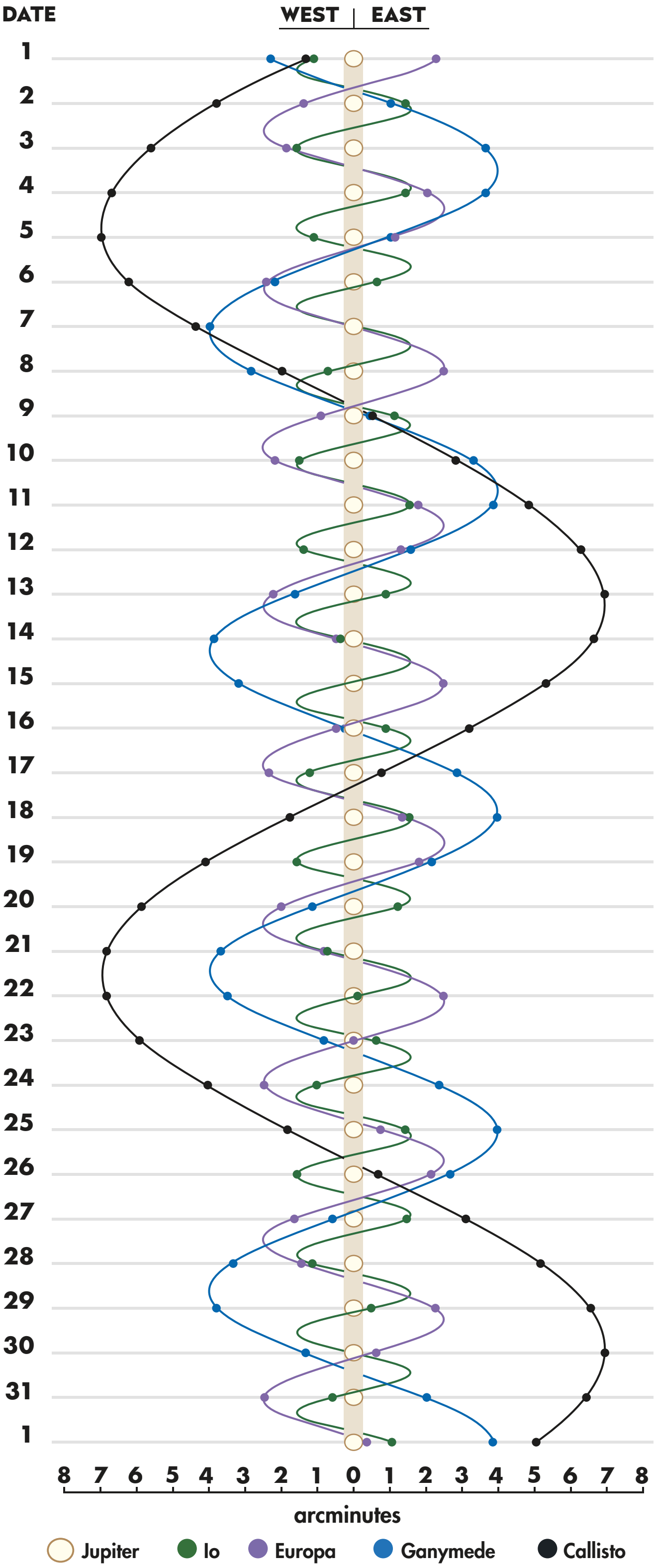
THE PLANETS IN JANUARY

The phase and relative sizes of the planets this month. Each planet is shown with south at the top, to show its orientation through a telescope



JUPITER'S MOONS JANUARY

Using a small scope you'll be able to spot Jupiter's biggest moons. Their positions change dramatically during the month, as shown on the diagram. The line by each date on the left represents 00:00 UT.



MERCURY

BEST TIME TO SEE: 1 January, 07:20 UT
ALTITUDE: 5° (low)
LOCATION: Ophiuchus
DIRECTION: Southeast

Mercury begins 2018 as a morning object, reaching greatest western elongation on New Year's Day. It rises two hours before the Sun on this date and, at mag. –0.2, stands out reasonably well against the dawn twilight. Look for it low towards the southeast horizon. On 12-15 January it has a close encounter with Saturn. Closest approach occurs on 13 January when both planets appear separated by 39 arcminutes. After 15 January, Mercury becomes tricky to see.

VENUS

BEST TIME TO SEE: 31 January, approximately 15 minutes after sunset
ALTITUDE: 0.5° (low)
LOCATION: Capricornus
DIRECTION: West-southwest

Venus starts the year as a morning object very close to the Sun. It reaches superior conjunction on 9 January but won't be visible. Its re-emergence into the evening sky is slow, but those with a flat west-southwest horizon and clear skies might catch a glimpse of mag. –3.8 Venus just after sunset on the 31st.

MARS

BEST TIME TO SEE: 6 & 7 January, from 05:00 UT
ALTITUDE: 10°
LOCATION: Libra
DIRECTION: Southeast

Mars starts the year as a morning object near Jupiter in Libra. The Red Planet currently has a magnitude of +1.5, but is rather distant and only shows a 4-arcsecond disc. By the end of the month the planet moves into Scorpius, approaching the mag. +1.1 summer star Antares (Alpha (α) Scorpii), the 'rival of Mars'.

SATURN

BEST TIME TO SEE: 13 January, 40 minutes before sunrise
ALTITUDE: 3.5° (low)
LOCATION: Sagittarius
DIRECTION: Southeast

Saturn is a morning object too close to the Sun to be seen properly at the start of January. By the middle of the month it will be far enough from the Sun's glare to be visible low in the southeast, given a flat horizon. Between 12-15 January it is close to mag. –0.2 Mercury; a beautiful 2%-lit waning crescent Moon joins the scene on the 15th. At this time Saturn will be at mag. +0.9.

URANUS

BEST TIME TO SEE: 1 January, 19:00 UT
ALTITUDE: 46°
LOCATION: Pisces
DIRECTION: South

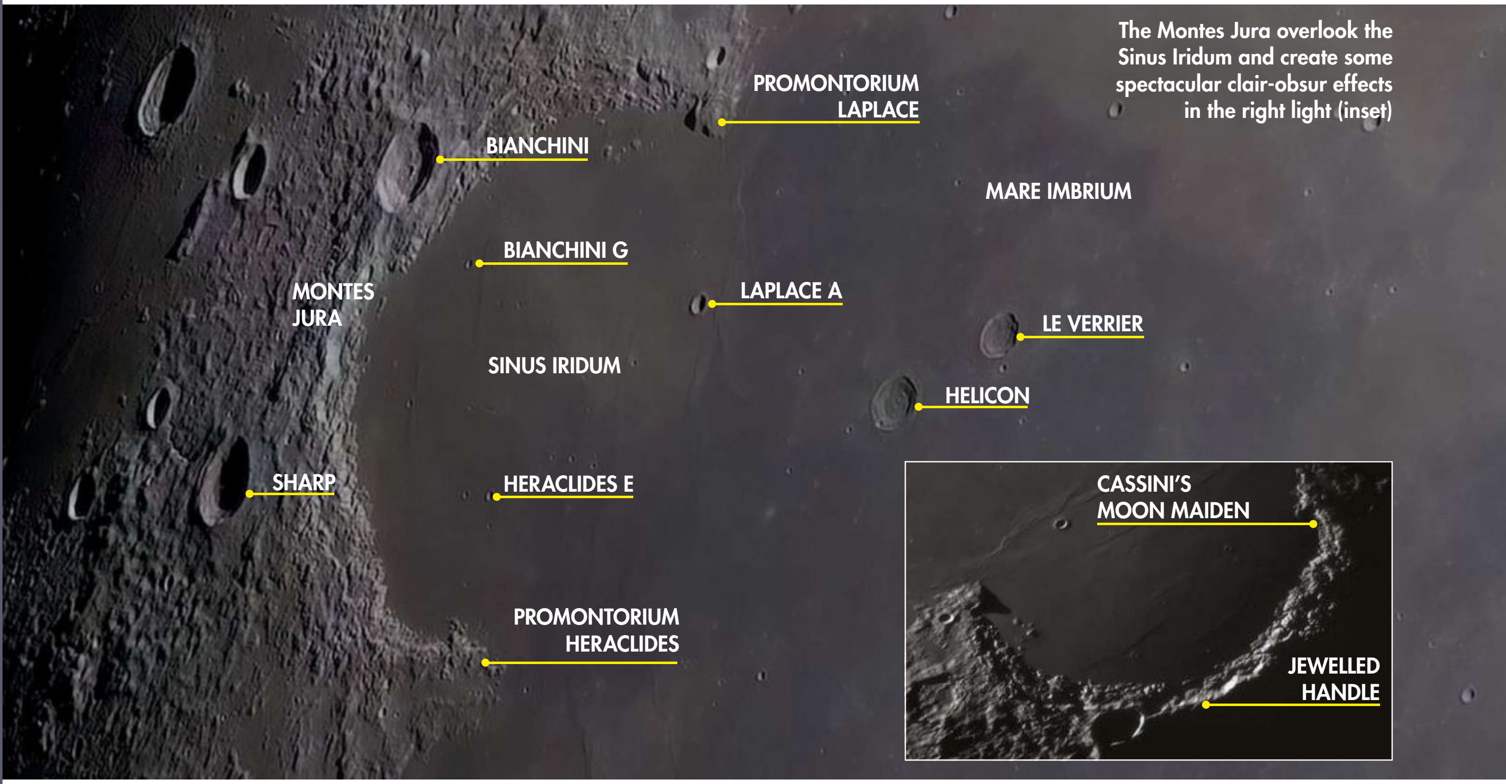
Mag +5.8 Uranus is well placed inside the 'V' of faint stars that forms part of the constellation of Pisces, the Fishes. It appears at its highest position, due south, in darkness at the start of January but the evening twilight delays its appearance until it is west of this position by the end of the month. From the centre of the UK, Uranus manages to achieve a very respectable altitude of 46° when due south, and this is the best time to attempt to view it.

NEPTUNE

BEST TIME TO SEE: 1 January, 18:00 UT
ALTITUDE: 25°
LOCATION: Aquarius
DIRECTION: South-southwest

Neptune is a reasonably well-positioned evening planet at the start of January but past its best towards the end. It shines at mag. +7.9 and is located close to mag. +3.7 Lambda (λ) Aquarii. The 11%-lit waxing crescent Moon is 2.5° south of Neptune on the evening of 20 January.

YOUR BONUS CONTENT Planetary observing forms

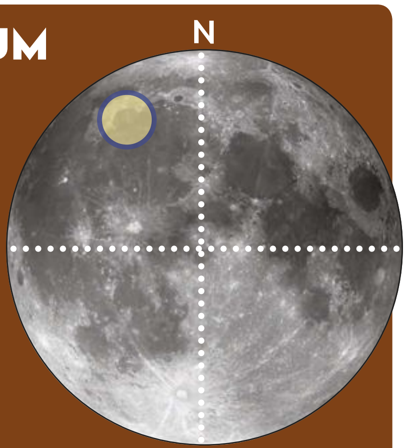


The Montes Jura overlook the Sinus Iridum and create some spectacular clair-obsur effects in the right light (inset)

MOONWATCH

SINUS IRIDUM

TYPE: Lunar Bay
SIZE: 400x260km
LONGITUDE/LATITUDE: 31.7°W, 45°N
AGE: Between 3.2-3.8 billion years old
BEST TIME TO SEE: Five days after first quarter (27-28 January) or two days after last quarter (10-11 January)
MINIMUM EQUIPMENT: 10x binoculars



Few lunar features have names that translate as beautifully as the Sinus Iridum – the Bay of Rainbows. This is a semi-circular protrusion from the northwest shore of the Mare Imbrium, the Sea of Showers. The Sinus Iridum looks like a bay off the larger sea. Its 'coastline', represented by the lighter lunar highlands, is prominently defined by the Montes Jura mountain range. Under the favourable light conditions around three days after first quarter, it may be possible to see the peaks of this range illuminated while the majority of the Sinus Iridum remains in darkness. This creates a clair-obscur effect known as the Jewelled Handle, the brightly lit mountains producing a beautiful arc of light that appears suspended above the background darkness. The effect is large enough that it can be seen through a pair of binoculars. The Jura range is partially interrupted along its northern edge by the 38km-wide crater Bianchini.

The ends of the bay are marked by two pointed headlands known as Promontorium Heraclides to the south and Promontorium Laplace to the north.

> **"When the illumination is more oblique, it's possible to see wrinkle ridges"**

Promontorium Heraclides produces another clair-obscur effect, known as Cassini's Moon Maiden. To see it, look at the feature around four days after first quarter: if the Maiden's visible, it will be in a south-up, inverted view. Both headlands cast distinctive pointed shadows across the surrounding surface when the illumination is right. Promontorium Heraclides rises 1.2km above the bay below, but is dwarfed by the Promontorium Laplace to the north, which towers nearly 3km above the surface.

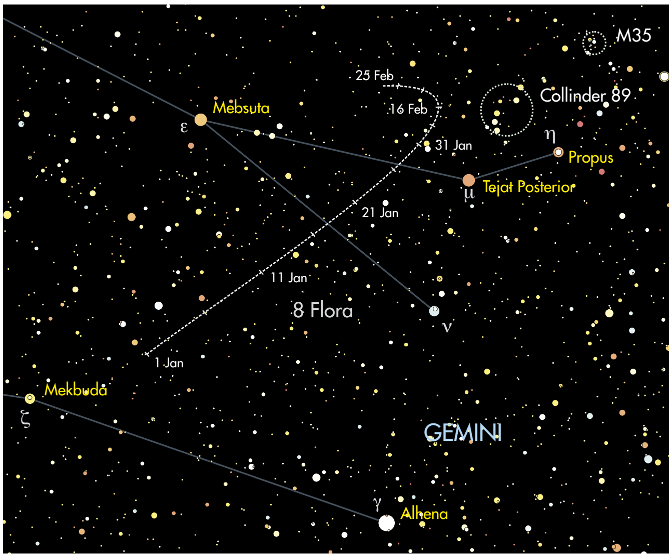
The surface of the bay looks remarkably smooth when the Sun is high. When the illumination is more oblique, however, it's possible to see a number of wrinkle ridges frozen into the basaltic lava that forms the Sinus Iridum's surface, giving the appearance of long, rolling waves heading towards the shore.

As you head out from the bay into the Mare Imbrium, you'll encounter two similar-looking craters, 25km Helicon and 20km Le Verrier. These almost appear as sentries to the bay. Almost on the actual entrance is 9km Laplace A, which should be visible with a 4-inch scope. Spotting features inside the bay is tricky because they're so small. The two largest craterlets are 4km Heraclides E, near to Promontorium Heraclides and 4km Bianchini G, near to its primary, close to the northern edge.

To the west of the Sinus Iridum, in the lighter highland surface, you'll find 40km crater Sharp. If you're an imager or have a large telescope, look at Sharp when the morning terminator is off to the west (approximately four and a half days after first quarter) and see if you can see a curious notch along the edge of the shadow cast by the crater's eastern rim. The notch is caused by a tiny, 1.6km craterlet, located right on the well-defined edge of Sharp's eastern rim.

COMETS AND **ASTEROIDS**

The path of asteroid Flora points the way to open clusters lurking near Gemini's feet



▲ **Asteroid Flora slips between the legs of Gemini during January, curving away in early February as it nears open clusters Collinder 89 and M35**

Asteroid Flora is well positioned this month, passing through the southwest part of Gemini, in the direction of a group of open clusters that reside close to the mythological twin Castor's foot. The asteroid starts the month as a binocular target of mag. +8.2, but fades by one magnitude to +9.2 by the end of January.

Flora was the second asteroid discovered by John Hind. His first was Iris, which he identified on 13 August 1847. Flora was discovered two months later on 18 October 1847. It's a large oblate body measuring 136x136x113km and is ranked as the seventh-brightest asteroid, with an average opposition magnitude of +8.7.

Flora reaches opposition on 2 January, half a magnitude brighter than this and close to its brightest achievable value of mag. +7.9. The asteroid reaches this peak brightness when opposition occurs close to Flora's perihelion position. It spins once on its axis every 12.8 hours.

It's a main belt asteroid, one of many orbiting between Mars and Jupiter and takes nearly four years to complete an orbit. Over this time its distance from the Sun varies between 1.86 AU and 2.55 AU. Flora is the closest of the large asteroids to the Sun and has the second closest mean orbital distance (2.20 AU) of the main belt asteroids, only beaten by 149 Medusa at 2.17 AU.

It is the lead member of the Flora family of asteroids, containing an estimated 80% of the group's mass. This is a large family of silicaceous, S-type, or stony asteroids, thought to be the source of the body that collided with our planet and led to the extinction of the dinosaurs.

By 10 February, Flora will be 1° east-northeast of the mag. +5.7 open cluster Collinder 89, which itself sits 2° east-southeast of mag. +5.1 M35. Consequently, a wide-angle sequence of images of this region from mid-January onward should reveal the movement of Flora towards the clusters. After 10 February, its track appears to bend north before continuing its journey northeast.

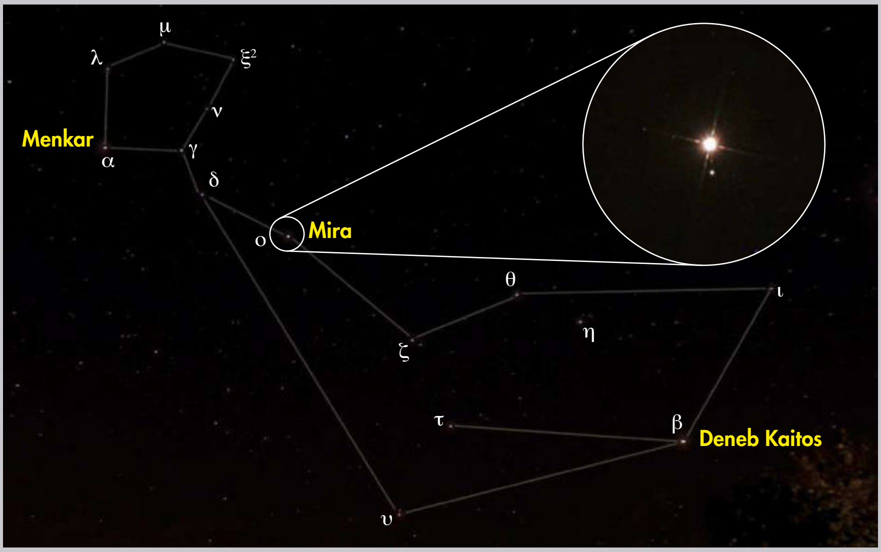
STAR OF **THE MONTH**

Mira – the pulsing variable threatening to go supernova

Mira is a red giant star located in the neck of Cetus that varies in brightness, pulsating on a 332-day cycle. When dimmest, a telescope is required to see it, but when brightest, it makes a noticeable contribution to its constellation.

Although its period is predictably regular, its brightness range isn't. When dimmest, Mira may appear anywhere between mag. +8.1 and +10.1. The maxima can vary too, ranging from mag. +4.9 to +2.0. Mira's next maximum occurs on 21 January 2018.

Following a spectacular supernova spotted in Cassiopeia by Tycho Brahe in 1572, German astronomer David Fabricius declared he had found a new star in Cetus during August 1596. Fabricius's new star was much dimmer and unlike the supernova, returned to view after fading. Years later, Johannes Holwarda determined the star's 11-month period, subsequently becoming known as the discoverer of Mira's true variability.

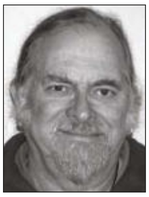


▲ **Although its brightness range varies widely, Mira's pulses on a regular 332-day cycle**

Johannes Hevelius named the star Mira in 1662. It means 'wonderful' or 'amazing'. Mira was one of the first regular variable stars identified and now lends its name to a whole class of them: the Mira-type variables. It lies at a distance of 300 lightyears and is catalogued as Omicron (ο) Ceti.

Mira is comprised of a red giant primary with a white dwarf companion orbiting at a close 70 AU. NASA's Chandra X-ray Observatory has seen matter being transferred from the red giant to the secondary. If the white dwarf re-ignites due to this transfer, it could cause a Type Ia supernova, the same type as that spotted by Tycho Brahe in 1572.

Ultraviolet observations, meanwhile, have revealed a 13-lightyear tail spreading behind the star – believed to be caused by Mira's stellar wind interacting with the interstellar medium.



STEPHEN TONKIN'S

BINOCULAR TOUR

Orion, Canis Major and Lepus point the way to January's best binocular targets

☑ Tick the box when you've seen each one

1 COLLINDER 70

10x 50 Most amateur astronomers have seen Collinder 70 without realising it: it's the oval-shaped OB association (a grouping of very young O- and B-type stars) surrounding Orion's Belt. On a clear night, you should be able to see at least 70 stars in this cluster. They are mostly of a blue-white (O and B spectral type) colour, with a few yellow stars interspersed. They form lots of pairs and some beautiful curved chains, in the swan's neck chain that weaves between mag. +1.7 Alnilam (Epsilon (ε) Orionis) and mag. +2.4 Mintaka (Delta (δ) Orionis). ☐ **SEEN IT**

2 SIGMA ORIONIS

10x 50 Look about 1° to the southeast of the easternmost star of Orion's Belt, mag. +1.9 Alnitak (Zeta (ζ) Orionis) – Sigma (σ) Orionis is the brightest star you will see, shining at mag. +3.8. With your binoculars, you will see that Sigma Orionis is, in fact, a multiple star. With a pair of 10×50s you will easily see two of the members, the white primary and the blue, 6th-magnitude component that lies 42 arcseconds away, towards Alnitak. In order to resolve the next two components, you will need at least double this magnification. The fifth member is not visible visually. ☐ **SEEN IT**

3 M42

10x 50 The Orion Nebula, M42, is a highlight of the winter skies and a superb object in binoculars of any size. It's the nearest stellar nursery to Earth and is visible to the naked eye as the central 'star' of Orion's sword. It's extremely sensitive to sky transparency and is usually best observed after rain has cleaned the sky of dust. On these occasions, the longer you look at it, the more intricate detail you'll be able to see. ☐ **SEEN IT**

4 M50

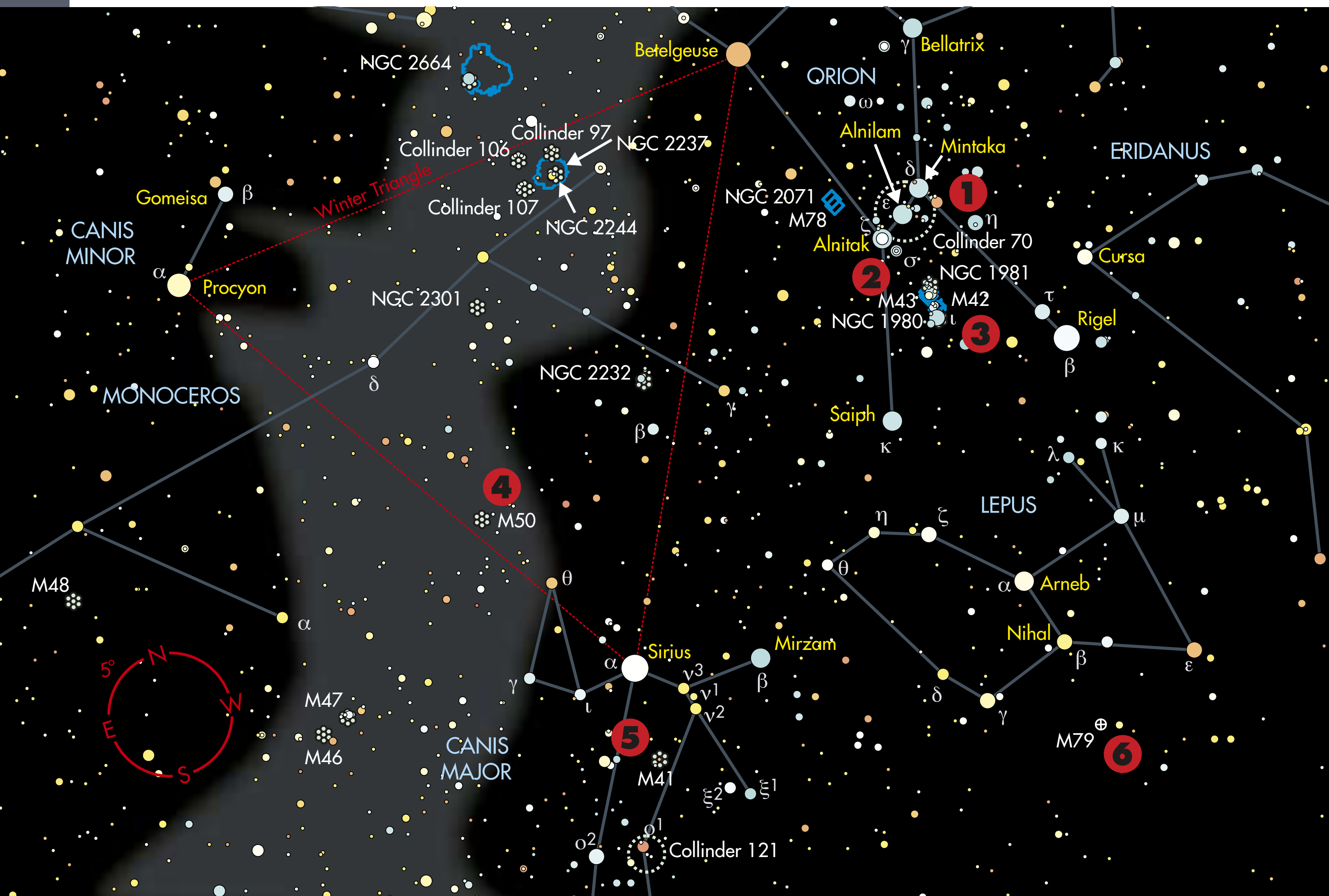
10x 50 The easy way to find M50 is to navigate a third of the way from mag. –1.5 Sirius (Alpha (α) Canis Majoris) to mag. +0.4 Procyon (Alpha (α) Canis Minoris). Here you'll find this lovely cluster, which appears as a heart-shaped glow about half the apparent diameter of the Moon. The glow comes from just over 100 stars, of which you should expect to resolve only four or five, depending on your sky conditions, using 10×50 binoculars. ☐ **SEEN IT**

5 M41

10x 50 M41 is a bright cluster 4° south of Sirius, visible to the naked eye in a transparent sky. It's larger and brighter than M50 and, in 10×50 binoculars from a reasonably dark site, you should be able to resolve up to 10 brighter stars against the background glow of fainter stars using averted vision. You may also be able to see that the stars differ in colour, with the brightest one, near the centre of the cluster, being somewhat orange. ☐ **SEEN IT**

6 M79

15x 70 This month's challenge is a mag. +8.2 globular cluster. First, identify mag. +2.6 Arneb (Alpha (α) Leporis), mag. +2.8 Nihal (Beta (β) Leporis) and mag. +3.6 Gamma (γ) Leporis. Extend a line from Arneb to Nihal southwards for just over 4°, where you will find a mag. +5.4 star. Without looking away from this star, avert your attention to a spot about 0.5° away in the direction of Gamma Leporis. Here you should see what looks like a star that is both fainter and larger than the mag. +5.4 one. This is the combined light of the 150,000 stars that comprise M79. ☐ **SEEN IT**



THE SKY GUIDE **CHALLENGE**

Find and picture the point in the sky that marks Earth's North Celestial Pole

A 15-minute exposure at ISO 100 through an f/3.3 telescope setup reveals enough rotation to allow for the identification of the true North Celestial Pole; Polaris is the brightest star visible

Our challenge this month is to see how many stars you can image or see between Polaris and the North Celestial Pole (NCP). The NCP is one of two positions in the sky representing the projection of Earth's spin axis. Imagine sitting on a swivel chair, spinning around and looking straight up. The spot on the ceiling that barely moves as you spin is the upper projection of the chair's spin axis. The star Polaris is special for the inhabitants of the northern hemisphere because it marks this position in the sky.

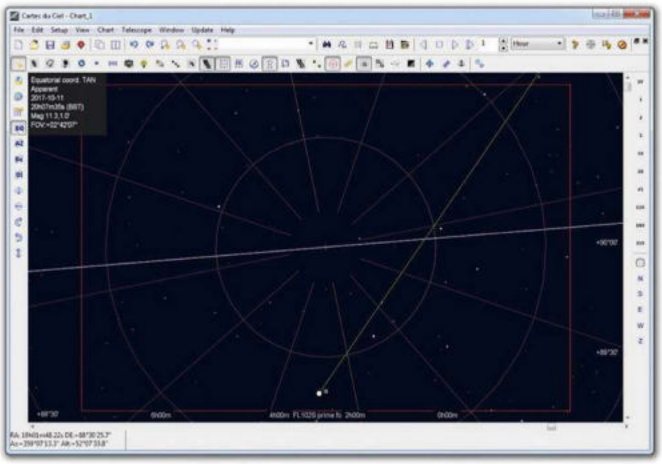
Polaris doesn't quite sit on the NCP. It's known as the Pole Star because at mag. +2.0 it is the closest naked-eye star to this position. A long exposure centred on Polaris shows stars moving concentrically around the NCP, with Polaris also describing a tiny arc around this position. This begs the question as to whether Polaris really is the closest star to the pole. Here, wide-angle star-trail photographs don't tend to have enough image scale to show the faint stars closer than Polaris.

A simple solution is to use a telescope. If you have one that's on a polar-aligned mount, turn the mount so that its polar axis points either east or west. With the mount's drive turned off, you can now point a camera-equipped telescope at the pole with ease. A low ISO setting will avoid over-exposing the sky too much, but as always, review your shots and experiment to ensure you get the best results.

Polaris sits about 40 arcminutes from the NCP, so an image scale giving a 2° short dimension on a DSLR frame and with the NCP centred, is ideal. Be prepared to take a few test shots to identify where the centre of rotation actually is. For a full-frame DSLR a focal length of around 600mm works well. For a typical non-full-frame DSLR (for example an APS-C sensor) 400mm will give a similar result.

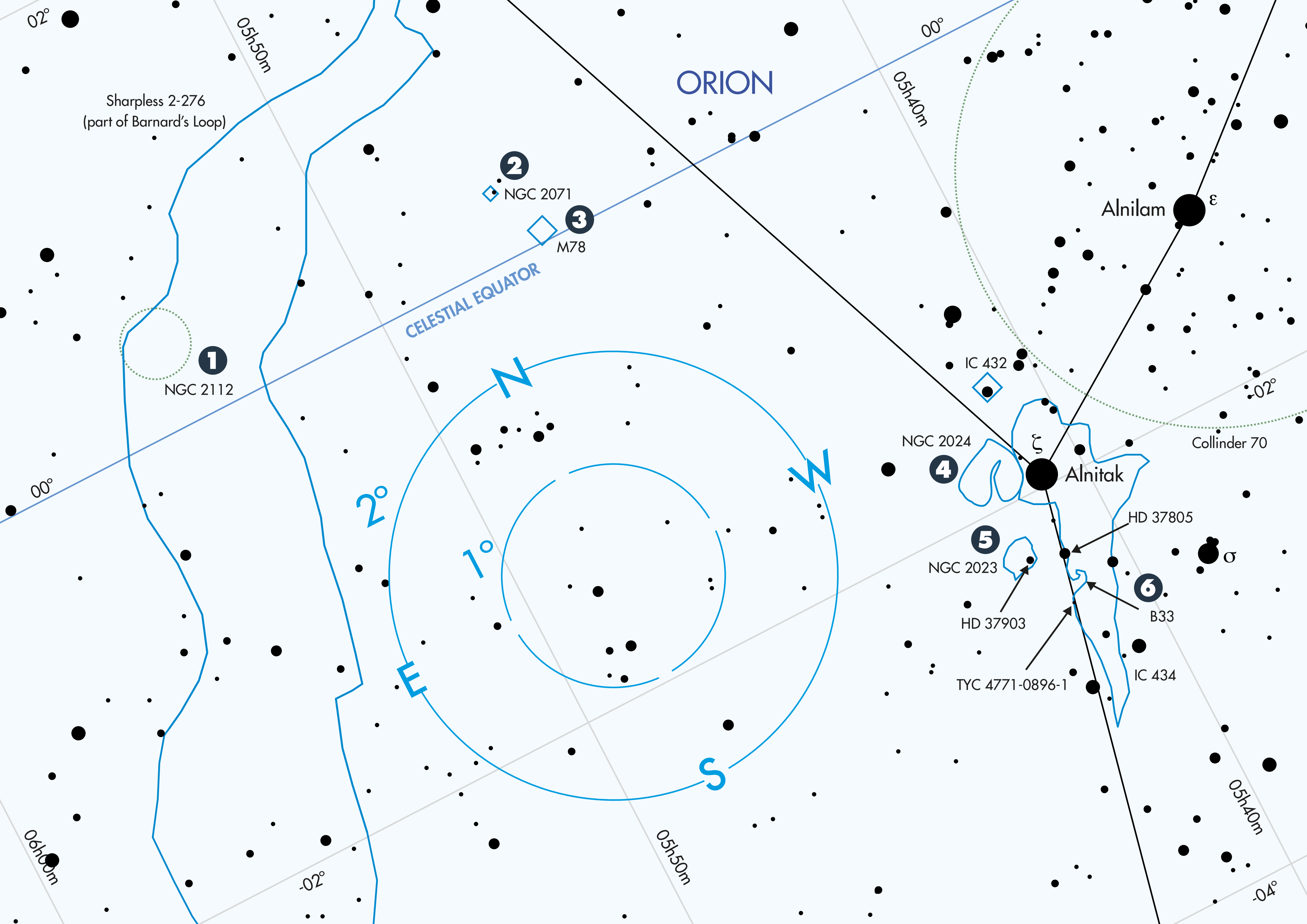
Rotation can be obtained by taking long exposures of 10-20 minutes each or, if sky brightness is an issue, by taking shorter exposures of between 1-5 minutes. Adding them together in an image editor, layering them and setting the blend mode of the upper layers to lighten will combine the trails. Alternatively, specialist star trail software such as StarTrails (www.startrails.de/html/software.html) can be used to achieve a similar effect.

Shorter exposures do have the advantage of making star identification easier, allowing you to match the result in a star chart in an attempt to identify the true pole star. The freeware Cartes Du Ciel is great for doing this. Bear in mind, however, that your result won't hold forever because the NCP moves, taking around 26,000 years to complete a circle of radius 23.5° in the sky.



▲ **Freeware Cartes du Ciel, with a full complement of downloaded catalogues, provides a great way to check your results**

PETE LAWRENCE X 3


ORION
Sharpless 2-276
(part of Barnard's Loop)
NGC 2071
M78
CELESTIAL EQUATOR
NGC 2112
IC 432
NGC 2024
Alnilam
ε
ζ
Alnitak
Collinder 70
HD 37805
σ
NGC 2023
HD 37903
B33
TYC 4771-0896-1
IC 434
N
W
E
S
1°
2°
1
2
3
4
5
6
02°
00°
-02°
-04°
05h50m
05h40m
06h00m

DEEP-SKY TOUR

See the clusters and nebulae that fill the sky around Orion's belt

☑ Tick the box when you've seen each one

1 NGC 2112

NGC 2112 is a 9th-magnitude open cluster in Orion. It's positioned behind one section of the gigantic, faint ring of nebulosity known as Barnard's Loop. The cluster is estimated to be 3,064 lightyears away, around twice the farthest distance estimate of the loop. NGC 2112 lies 4° northeast of mag. +1.9 Alnitak (Zeta (ζ) Orionis). It's fairly rich, containing around 100 stars, many of which are around 12-13th magnitude. This is a rich area of sky, which makes it easy to lose NGC 2112 against the background. Using a low power, a 6-inch scope shows a granulated glowing patch approximately 6 arcminutes across. A 10-inch scope resolves about 35 members against a haze around 10 arcminutes across. ☐ **SEEN IT**

2 NGC 2071

Head 1.7° west from NGC 2112 and you'll arrive at NGC 2071. This is an 8th-magnitude reflection nebula located 0.25° northeast of our third target, M78. There is often confusion here as M78 is also a reflection nebula. NGC 2071 is visible in a small telescope as a faint hazy glow. A good strategy when using smaller apertures is to use averted vision, looking slightly to the side of the nebula to place its delicate light on a more sensitive part of your retina. NGC 2071's glow appears about the same as that of a 10th-magnitude star. Larger apertures show it off-centre with respect to the star, most of the nebulosity appearing to the south. ☐ **SEEN IT**

3 M78

M78 is an easy find from NGC 2017, sitting just 0.25° farther southwest. This reflection nebula is a lovely sight in a small telescope. Listed at mag. +8.3, it appears as a misty glow with two embedded stars of similar brightness. The overall appearance is like that of a car with its headlights on at night, approaching through fog. A 6-inch scope shows an oval shape with a longest dimension of 6 arcminutes. Careful scrutiny reveals a non-uniform brightness, portions of the nebula to the north shining slightly brighter than the rest. When viewed through larger apertures M78 appears to widen towards the southeast, showing a sharp edge to the northwest. ☐ **SEEN IT**

4 NGC 2024

NGC 2024 is enigmatically named the Flame Nebula. It's large and very detailed, but suffers from close proximity to the bright star Alnitak at the eastern end of Orion's Belt. The centre of the nebula is 17 arcminutes east-northeast of the star. A 6-inch scope shows a glowing region bifurcated by a dark line. The easiest way to see detail is to use a low power and place Alnitak out of the field of view. An 8-inch instrument begins to show dark tributaries branching off the central, 3-arcminute-wide dark lane, giving an appearance similar to a glowing leaf. The larger the scope, the more of these dark tributaries can be seen. ☐ **SEEN IT**

◄ **NGC 2024, NGC 2023 and B33, the Horsehead Nebula, form a line running under bright Alnitak**

THIS DEEP-SKY TOUR HAS BEEN AUTOMATED

ASCOM-enabled Go-To mounts can now take you to this month's targets at the touch of a button, with our Deep-Sky Tour file for the EQTOUR app. Find it online.

5 NGC 2023

There's another bright reflection nebula close to Alnitak but this one looks completely different to the Flame Nebula. NGC 2023 is 21 arcminutes east-southeast of Alnitak and is relatively easy to see through a 6-inch scope. It surrounds 8th-magnitude star HD 37903, around which it gives the appearance of a mottled glowing cocoon, fading in brightness from the centre out. At around 10 arcminutes across, NGC 2023 is much smaller than the 30-arcminute-diameter Flame Nebula and being circular means it can disguise itself like a star at low magnifications. NGC 2023 is estimated to be four lightyears across, making it one of the largest-known examples of a reflection nebula. ☐ **SEEN IT**

6 THE HORSEHEAD NEBULA

Our final target is the Horsehead Nebula, Barnard 33, and it can be found 28 arcminutes south of Alnitak. This is a finger of dark nebulosity protruding across a brighter curtain formed by emission nebula IC 434. A dark, clear sky and dark-adapted eyes are essential here. The first step in locating the Horsehead is to identify the background curtain of IC 434. Using a low power of around 50x, look for the dark intrusion along its eastern edge between mag. +7.5 HD 37805 and mag. +10.9 TYC 4771-0896-1. A UHC or hydrogen-beta filter will make seeing the dark intrusion easier but don't be disheartened if you can't see it – Barnard 33 can be quite challenging. ☐ **SEEN IT**

YOUR BONUS CONTENT

Print out this chart and take an automated Go-To tour

CHART: PETE LAWRENCE, PHOTO: ISTOCK

ASTROPHOTOGRAPHY

A beginner's guide to photographing the Moon

RECOMMENDED EQUIPMENT

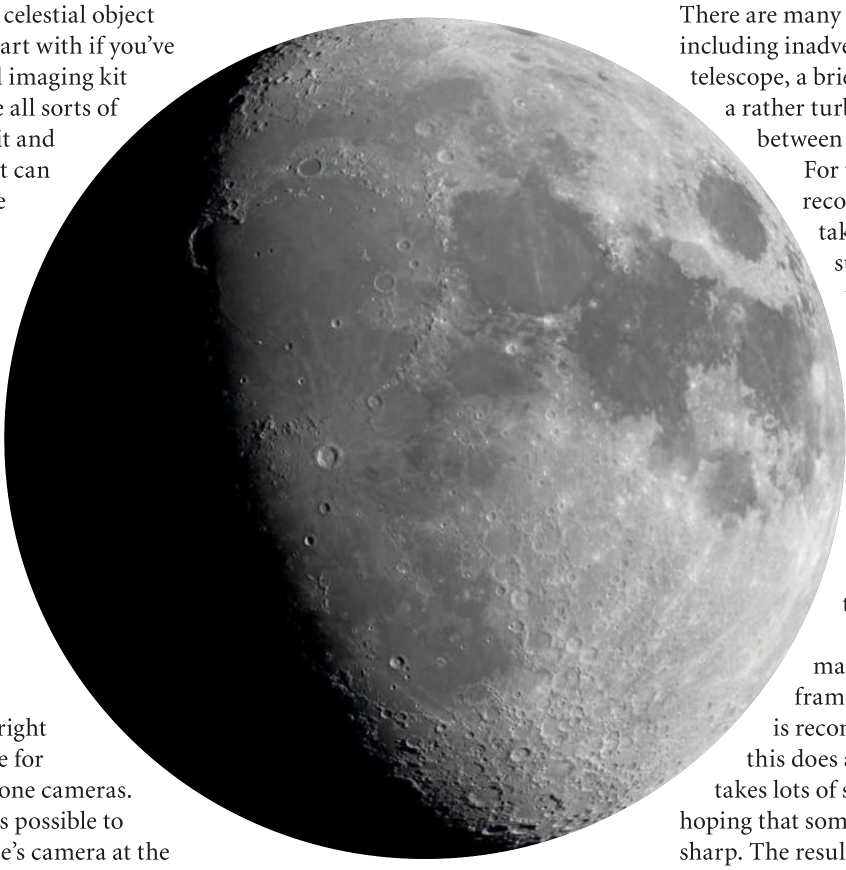
DSLR or high frame rate planetary camera, telescope, tracking mount

The Moon is a beautiful celestial object and a perfect target to start with if you've been given astronomical imaging kit for Christmas. There are all sorts of different ways to image it and many levels of detail that can be attempted. One of the most rewarding ways to photograph the Moon is to attach a camera to your telescope, using the scope as a super-telephoto lens. Adaptors can be obtained for most types of camera that will enable them to be coupled directly to the eyepiece holder of your scope.

Even if you don't have a specialist adaptor, a telescope fitted with an eyepiece, focused on a bright Moon can act as a source for devices such as smartphone cameras. With a bit of practice, it's possible to carefully point the phone's camera at the bright image presented in the eyepiece and take a shot. The camera will work out the settings for you and often give a surprisingly good result.

A DSLR attached to a telescope is another way to produce great images of the Moon. Set the camera to manual, select a low ISO value of say 100-200, a short exposure and take the shot. A remote shutter release is highly recommended, as it will help prevent the scope shaking when you press the shutter button. The same thing can be achieved by setting the delay timer if you don't have a remote shutter release.

How short the exposure needs to be depends on factors such as the current phase of the Moon and the focal length of your scope. Start out with an exposure of 0.5 seconds and review the results. If the image is overexposed, shorten the exposure; if it's underexposed, increase the exposure. A tracking mount is recommended to get the sharpest shots, but if you don't have one, increasing the ISO should allow you to keep exposures short enough to avoid significant motion blur. This blur is due to the Earth's rotation. Just be aware that increasing ISO will also increase noise.



▲ The Moon is great target for developing your astrophotography skills

ALL PIUCTURES: PETE LAWRENCE

Experienced lunar photographers can determine whether the shot they've just taken is over- or underexposed by assessing the image as it appears on their camera's review screen. For less-experienced imagers, however, there's a more surefire method of checking your results via the camera's histogram display. The process for doing this is covered in the step-by-step guide, opposite.

Focus is also very important and for a stills camera it's important to realise that even if you've spent ages focusing on those dramatic and sharp lunar shadows, it's still possible to take blurred shots. There are many reasons why this happens including inadvertently knocking the telescope, a brief gust of wind or simply a rather turbulent region of air between you and the Moon.

For this reason, it's always recommended that you take many shots in quick succession. More often than not, what looks sharp on the back of the camera may turn out to be quite soft when viewed on a computer screen. Taking lots of shots increases the chance that you've caught at least one or two that are sharper than the rest.

For close-up, highly magnified shots, a high frame rate planetary camera is recommended. In many ways this does a similar thing, in that it takes lots of shots in rapid succession, hoping that some of them will appear sharp. The resulting movie sequence can be processed using one of the excellent freeware registration-stacking tools that are available online.

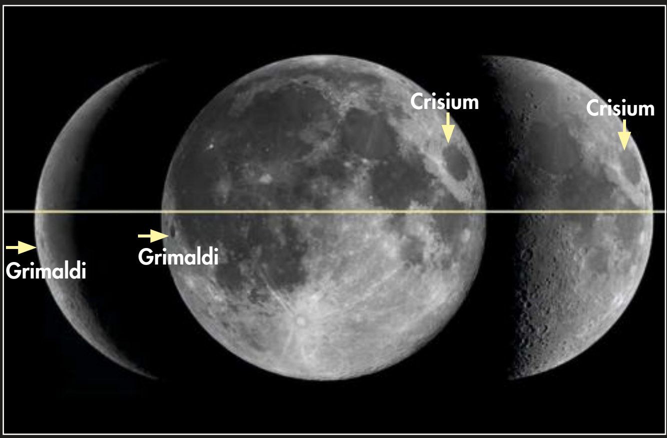
KEY TECHNIQUE

CONSIDER EVERY ASPECT

Unlike most astrophotographic targets, the Moon is big, bright and shows sharp relief detail, which is perfect for focusing. The Moon's brightness means that virtually any imaging device should be able to obtain a good shot. But there are many pitfalls for the unwary lunar photographer. Focus, composition, orientation and exposure are just a few of the factors that need to be considered when attempting a lunar image. Courses in lunar photography are useful for teaching you the basics and refreshing your skills if you already have some experience of astrophotography.

✉ Send your image to: hotshots@skyatnightmagazine.com

STEP BY STEP

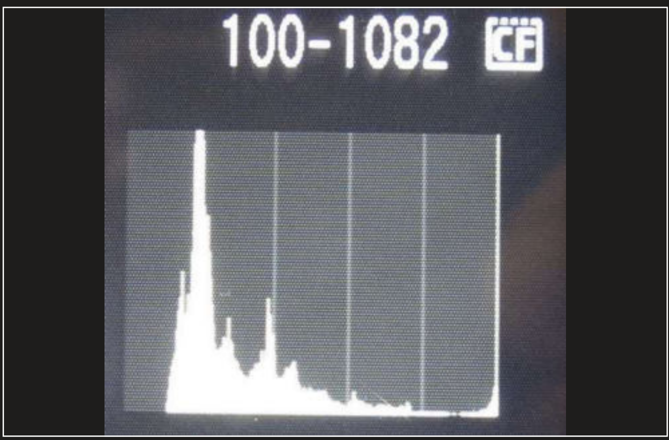


STEP 1

A common error made when framing a Moon image through a scope's diagonal is to have it mirrored. Two features give basic orientation during the lunar cycle: Mare Crisium in the east and dark-floored Grimaldi near the western limb. With north up, Crisium should be to the right above the horizontal centre line. Grimaldi should be to the left below the centre line.

STEP 2

Take your time focusing. Slowly approach the point of focus from one side and move past it to defocus the image. Then reverse direction and repeat the process. When you're confident you know where focus is, snap to that position. Get into the habit of checking focus often as temperature variations can move the point of focus slightly.

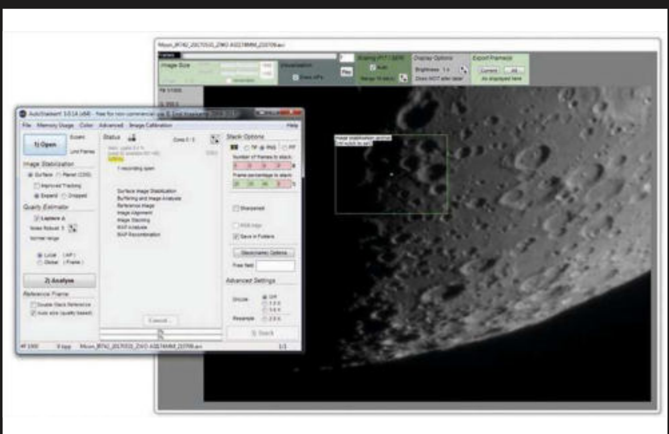


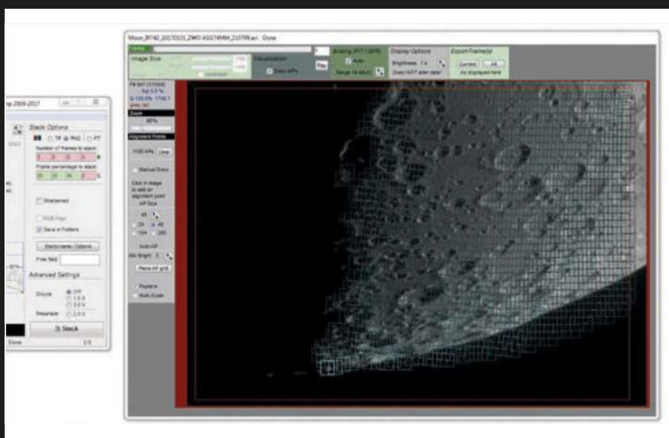
STEP 3

DSLRs and other types of digital camera have histogram displays to help get the perfect exposure. The basic rule is to keep the main data block within the edges of the graph, avoiding sharp 'cliff' edges at either end. For high frame rate cameras, the control software should display a live levels meter. Keep this between 70-80 per cent of peak.

STEP 4

A monochrome, high frame rate camera works best on the Moon as you can avoid complications due to atmospheric dispersion that can cause colours to misalign. Fitting a red or infrared pass filter restricts the colours entering the camera to avoid this. These filters also stabilise the view as longer wavelengths are less affected by atmospheric seeing.





STEP 5

Multiple image captures need to be registered and stacked. Using freeware Autostakkert (www.autostakkert.com), click Open and select capture file. For close-ups, select surface. Hold Ctrl and left click on a well-defined feature. Click Analyse. Set the 'Number of frames to stack' and 'Frame percentage to stack' boxes – try 20, 30 and 40 per cent to start.

STEP 6

Select a small alignment point ('AP Size') and click 'Place AP grid'. If shadowed features aren't covered, lower 'Min Bright' and click 'Place AP grid' again. You can also add AP boxes by clicking on a feature. Press the Stack button. When processed, the results are stored below the movie folder. These may be sharpened in an image editor.

GO FOR LAUNCH

ISTOCK

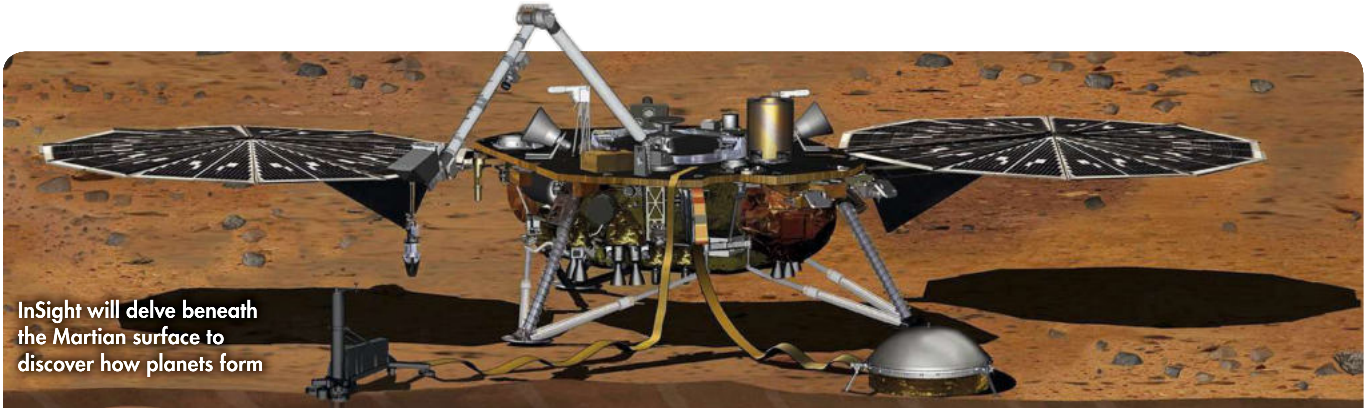
There are some fantastic missions lifting off in 2018. **Elizabeth Pearson** looks forward to the explorations and observations we can expect in the year ahead

Over the coming 12 months humanity is set to explore more of our Solar System and the space beyond it, thanks to a host of missions set for launch in 2018.

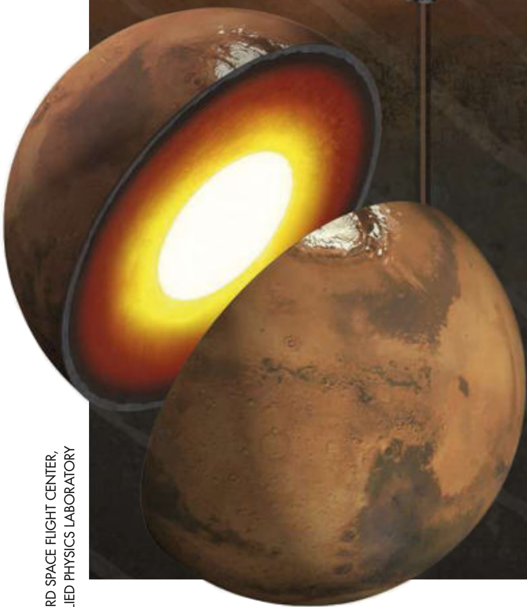
This year there'll be a focus on our rocky neighbours with missions to the Moon, Mars, Mercury and asteroids. Meanwhile, exoplanet hunters will set about trying to find ever more terrestrial planets outside our Solar System. Private companies are also pushing further into space as they race to land on the Moon and compete to carry astronauts to the International Space Station.

Unfortunately, several of the largest missions intended for launch in 2018 have been delayed. The long-awaited James Webb Space Telescope has been pushed back to 2019, as has ESA's Solar Orbiter. Meanwhile, the Chinese lunar exploration programme is only just getting back on track following the failure of a Long March 5 rocket in July 2017.

But despite these setbacks, 2018 is set to be a fantastic year for learning more about our Galaxy. ▸



InSight will delve beneath the Martian surface to discover how planets form



Mars

Another robotic explorer is bound for the Red Planet to investigate its interior

No planet has captured the imagination of planetary explorers quite like Mars. In May, NASA will launch InSight (Interior Exploration Using Seismic Investigations, Geodesy and Heat Transport), a lander that will look into the heart of the Red Planet.

InSight is due to touch down on the Martian surface in November on Elysium Planitia, a flat area near the planet's equator. Once there it will examine Mars from surface to core. By feeling for the slight wobble of Mars as it spins, taking seismic measurements and observing the heat flow through the planet, InSight will help planetary scientists on Earth build up a full picture of what's happening within the Red Planet.

Mars is a planet frozen in time: it has barely changed from its early formation. While Mars was large enough to pull itself into a sphere and differentiate its internal structure into a core, a mantle and a crust, it was so small that it quickly cooled, solidifying the structure in place rather than continuing to evolve as Earth has done. By peering into the planet with Insight, researchers are planning on taking full advantage of this freeze-frame of what early planets looked like.

Asteroids

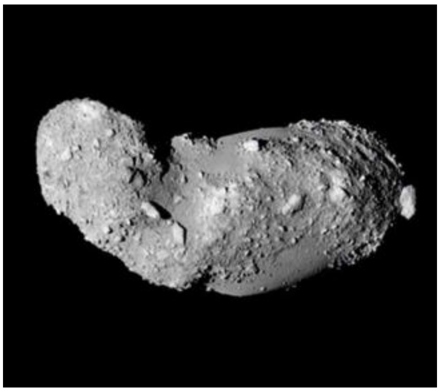
Asteroids can tell us a lot about how planets formed

While most missions are just beginning their journeys in 2018, two spacecraft will be about to start their science phases this summer, when Japan's Hayabusa 2 reaches asteroid Ryugu and NASA's OSIRIS-REX reaches asteroid Bennu.

The two missions have very similar goals, despite being completely separate. Both intend to spend several years mapping their respective asteroids before attempting to scoop up around 2kg of material from their surfaces. Both Ryugu and Bennu are carbon-rich asteroids – the most primitive kind of space rocks that were left over from the formation of the planets – and have remained largely unchanged since the early days of the Solar System.

Their samples will be returned to Earth – Hayabusa2's in 2020, OSIRIS-REX's in 2023 – giving geologists a pristine sample of what made up the primordial planets.

OSIRIS-REX will also watch the effect of the Sun's light on the motion of the asteroid. Not only will this help us calculate the orbits of potentially hazardous space rocks more accurately, it could also teach us how we might deflect asteroids from potentially life-threatening impacts in future.



▲ Hayabusa 2 will be sent to survey the carbonaceous asteroid Ryugu

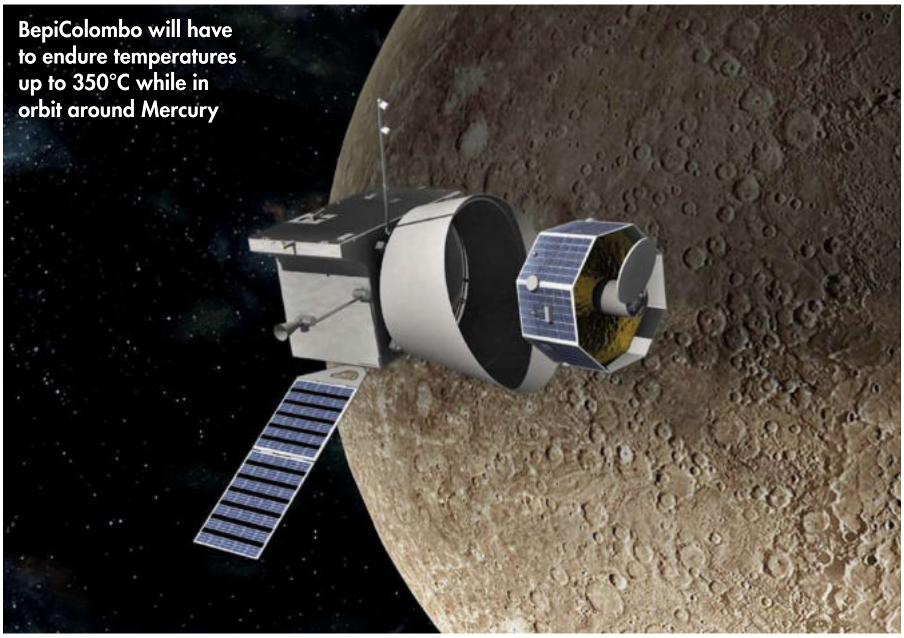
Hayabusa 2 will map Ryugu and return a sample of the asteroid to Earth

OSIRIS-REX will carry cameras, an altimeter and a spectrometer to investigate the near-Earth asteroid Bennu

NASA/JPL-CALTECH X 2, ISAS/JAXA, JAXA/AKIHIRO IKESHITA, NASA'S GODDARD SPACE FLIGHT CENTER, ASTRIUM, XINHUA / ALAMY STOCK PHOTO, JOHNS HOPKINS UNIVERSITY APPLIED PHYSICS LABORATORY

Mercury

Our smallest planet could give us a window onto worlds around other stars



BepiColombo will have to endure temperatures up to 350°C while in orbit around Mercury

Only two spacecraft have ever been sent to explore the closest planet to our Sun, Mercury. But that number is set to double as two science stations are launching towards the planet together in October as part of the BepiColombo mission – the European Mercury Planetary Orbiter (MPO) and the Japanese Mercury Magnetosphere Orbiter (MMO).

Planetary scientists have a renewed interest in Mercury as it's our best analogue for the hundreds of rocky exoplanets that have been discovered in close orbits around stars outside our Solar System over the last few decades. The MPO will study how being blasted by solar radiation affects a hot rocky planet, as well as map Mecury's surface, measure the planet's topography and mineral content, and gravitationally chart its internal structure.

Meanwhile, the MMO will attempt to solve the mystery of Mercury's magnetic field. The field is probably generated by a molten core, but no one knows why Mercury would still have a molten core when the larger Venus and Mars both appear to have frozen.

Getting all this information will take time, however, as it will take several years for BepiColombo to speed up enough to match speed with the planet. The spacecraft is expected to eventually settle into orbit around Mercury in 2025.

The Moon

Our neighbour is about to get more visitors

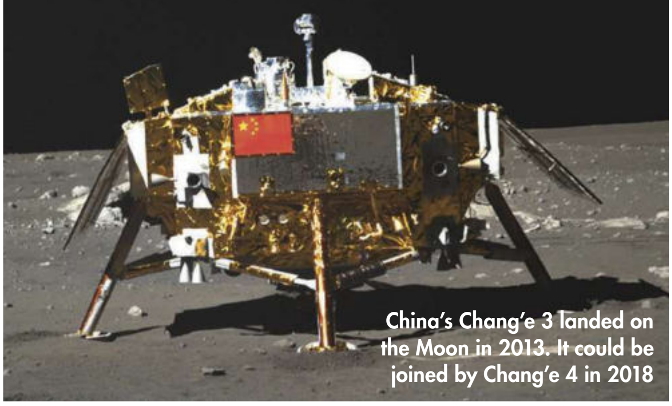
As more nations and private companies venture into space, they're looking to cut their teeth on the proving ground of planetary exploration – the Moon.

The Chinese National Space Administration (CNSA) aims to cover new ground with Chang'e 4 and land on the far side of the Moon. This mission is currently aiming for the oldest and largest impact feature on the Moon, the South-Polar Aitkin Basin.

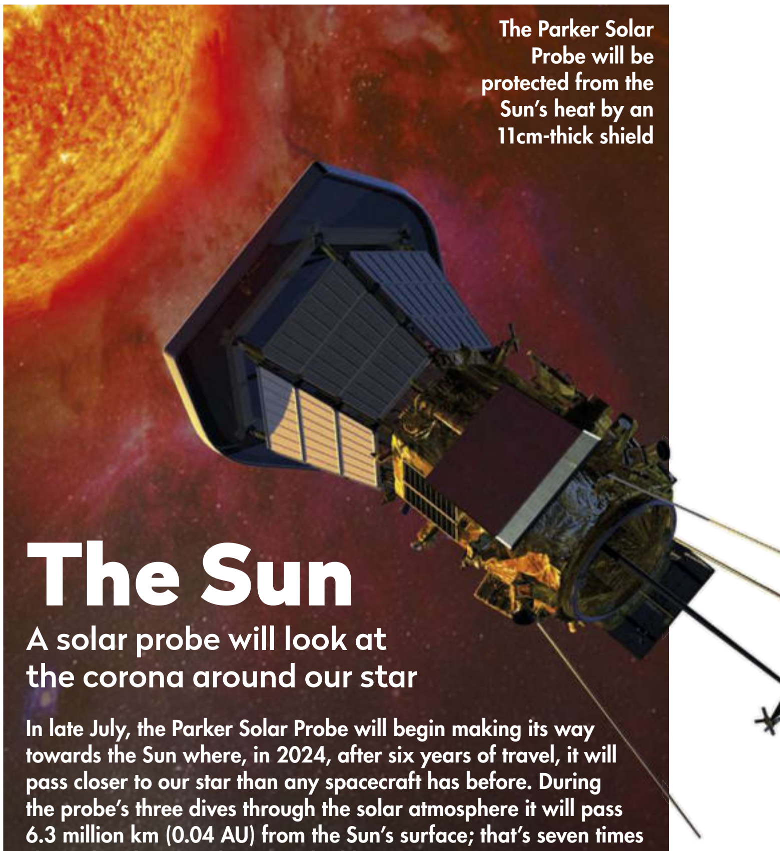
As ground control cannot communicate directly with the far side of the Moon, a relay station is due to be launched for lunar orbit in May 2018. The main mission is expected to follow approximately six months later.

CNSA could also send the first-ever uncrewed sample return mission to the lunar near-side, Chang'e 5, at the end of the year, though this could be pushed back until 2019.

But China isn't the only one going back to the Moon. On 31 March, the deadline to land a privately funded rover on the Moon and win the Google Lunar X Prize is finally up. Five teams – Moon Express, SpaceIL, Synergy Moon, Team Indus and Hakuto – are set to make the deadline. The race for the Moon is back on.



China's Chang'e 3 landed on the Moon in 2013. It could be joined by Chang'e 4 in 2018



The Parker Solar Probe will be protected from the Sun's heat by an 11cm-thick shield

The Sun

A solar probe will look at the corona around our star

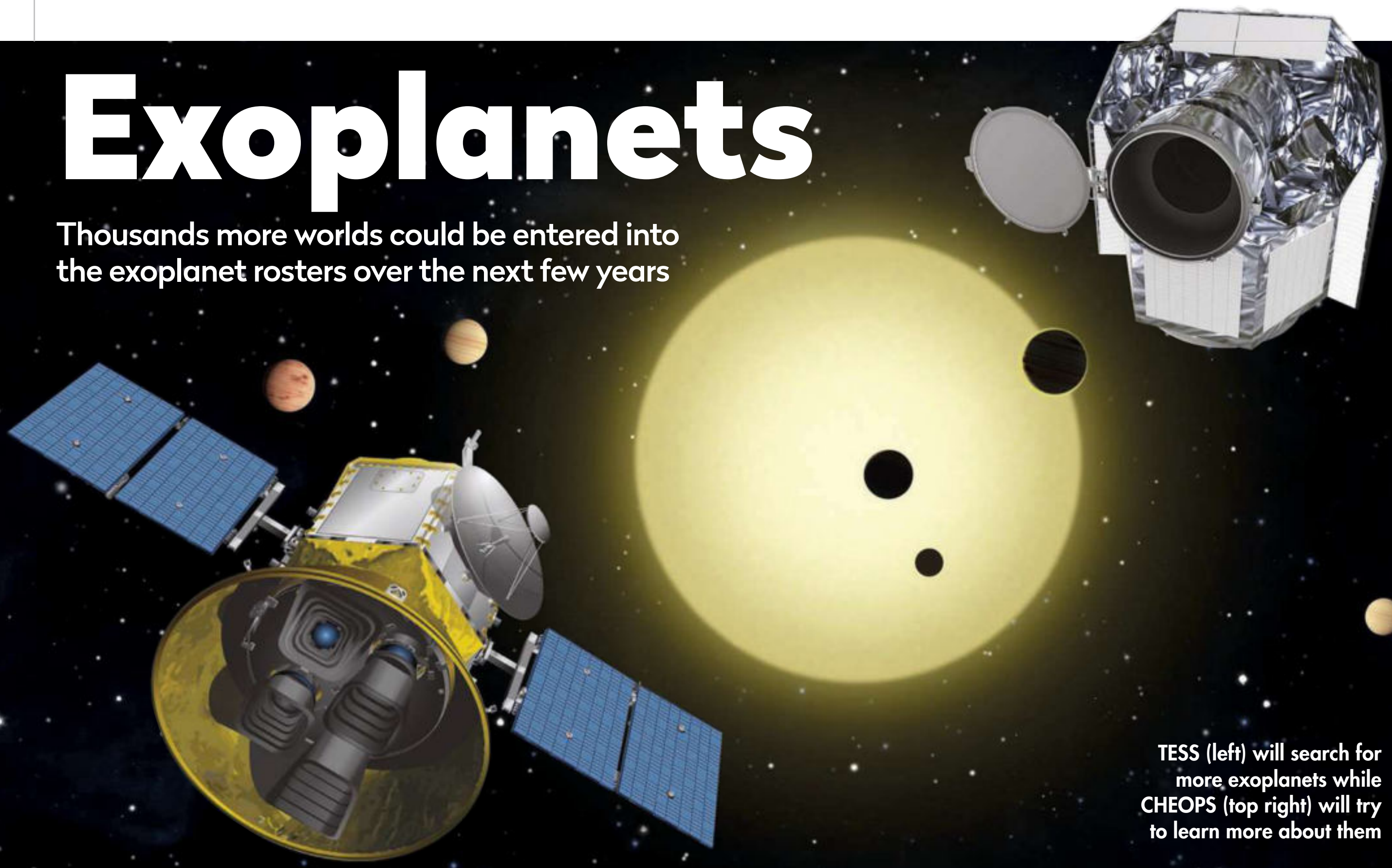
In late July, the Parker Solar Probe will begin making its way towards the Sun where, in 2024, after six years of travel, it will pass closer to our star than any spacecraft has before. During the probe's three dives through the solar atmosphere it will pass 6.3 million km (0.04 AU) from the Sun's surface; that's seven times closer than has ever been reached by an active mission.

During these passes, Parker will explore how heat and energy flow through the solar corona. The region has intrigued solar scientists for over 60 years, but it is only now that NASA has been able to build a probe capable of withstanding the 1,380°C temperatures to explore the region.

As well as providing a better understanding of this area around the Sun, the findings could also help researchers predict solar flares and space weather that might harm life on Earth. ▸

Exoplanets

Thousands more worlds could be entered into the exoplanet rosters over the next few years



TESS (left) will search for more exoplanets while CHEOPS (top right) will try to learn more about them

Exoplanets are one of the hottest areas of astronomical research, and now two new dedicated satellites will be joining in the quest to find and categorise these planets.

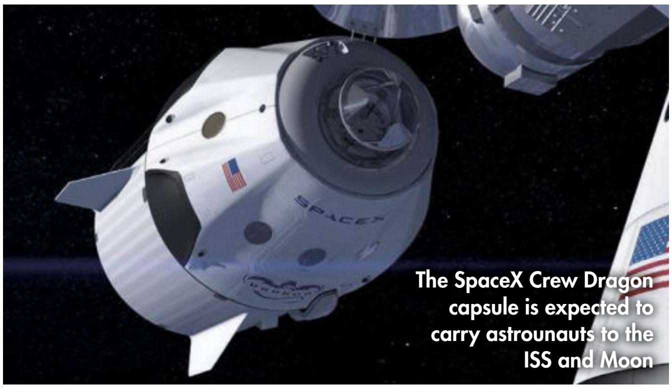
The Transiting Exoplanet Survey Satellite (TESS), due for launch in 20 March 2018, will monitor over 20,000 stars looking for the temporary dips in brightness caused by planets passing in front of them. Over its two-year mission, TESS will cover 400 times the sky area of its predecessor, Kepler. The team behind TESS hope to find 1,500 exoplanet candidates, of which 500 are expected to be Earth or super-Earth sized.

But exoplanet research is about more than just finding these planets. ESA's Characterising Exoplanet Survey (CHEOPS) satellite, is due to launch in 2018 too, and it will look at already-known exoplanets and attempt to take highly precise measurements of their radii. Combined with mass measurements, these observations will make it possible to determine the density of exoplanets and gauge whether they are rocky worlds or gas giants.

Crewed missions

Two new crew transporters could be about to change the face of spacefaring

To reduce crew training time the Boeing Starliner has been built to dock with the ISS autonomously



The SpaceX Crew Dragon capsule is expected to carry astrounauts to the ISS and Moon

MIT, NASA/TIM PYLE, ESA/C. CARREAU, BOEING, SPACE X

If you want a ride to the International Space Station, at the moment you have to hitch a lift on a Russian Soyuz spacecraft. But that's set to change in 2018, as both Boeing and SpaceX are preparing to put their crewed capsules into space for the first time.

The spacecraft are being built as part of NASA's Commercial Crew Program, which tasked private companies with creating new systems for human space access from US soil. Both Boeing's CST-100 Starliner and SpaceX's Crew Dragon have been designed to hold up to seven astronauts and be as user friendly as possible to reduce training time.

Both companies aim to prove their craft's safety with an uncrewed orbital demonstration over the summer ahead of a second test that will take an astronaut to the ISS and back. S

ABOUT THE WRITER

Dr Elizabeth Pearson is *BBC Sky at Night Magazine*'s news editor. She gained her PhD in galactic astronomy at Cardiff

IMAGING FOR SCIENCE

Part 4: Comets

Your photos can provide key information on the comets orbiting around our Solar System. Pete Lawrence explains how...

ABOUT THE WRITER
Pete Lawrence is an expert astronomer and astrophotographer who holds a particular interest in digital imaging

Amateur observations of comets can make a real contribution to science. But it's recommended that you calibrate your PC or camera clock to an atomic time source before you begin any observations as astrometric and photometric measurements require timing precision. The date of observations should be noted, with time given in UT accurate to 0.00001 day (0.864 seconds). It's also important to note the equipment used, including any filters, and the sky conditions.

If you plan to submit images or astrometry (measurements of position and movement) and photometry (measurements of brightness) to organisations such as the British Astronomical Association (BAA) you'll need to use its standard format. For an image, indicate its orientation along with a scale; the convention for comet images sent to the BAA is to show north at the top and east to the left.

Astrometric measurements will need to have the precise location that the measurement was taken, including latitude, longitude and altitude. Observatories registered with the Minor Planet Center will have a code against which this information is held in a central database.

Hardware & Software

HARDWARE
Binoculars, small and large telescopes, DSLR and CCD cameras

SOFTWARE
Astrometrica. Shareware, €25 (www.astrometrica.at)
Comphot. BAA comet photometry (www.britastro.org/node/11124)
Deep Sky Stacker (deepskystacker.free.fr)
Pixinsight (pixinsight.com)
Gimp/Photoshop (www.gimp.org)

Submit your pics for science

"Comets are fascinating objects to observe. They are also scientifically very important since they represent material left over from the formation of the Solar System, which has been kept in deep freeze for billions of years," says Nick James (pictured), director of the British Astronomical Association Comet Section.

"A rare, bright comet can be an extraordinary sight in the sky and even the more mundane objects often behave in ways that we don't expect. You never quite know what you will see when you go out to observe one.

"The Comet Section has been around since 1891 and we aim to encourage observations of these enigmatic objects, both for pleasure and to provide valuable scientific data. As with many areas of astronomy we have benefited from the revolution in digital imaging systems over the past few decades and our section officers have then necessary expertise to help observers record their sightings.

"When a comet is first discovered it's important to characterise its orbit and a number of our observers submit very accurate position measurements obtained from images. Once the orbit is secure we can characterise the comet's activity by measuring how its brightness evolves. Despite recent developments in digital imaging, visual observers still excel in this area. In fact, visual observations are often crucial in understanding the behaviour of a comet since they allow us to compare recent observations with observations made using similar techniques many years ago.

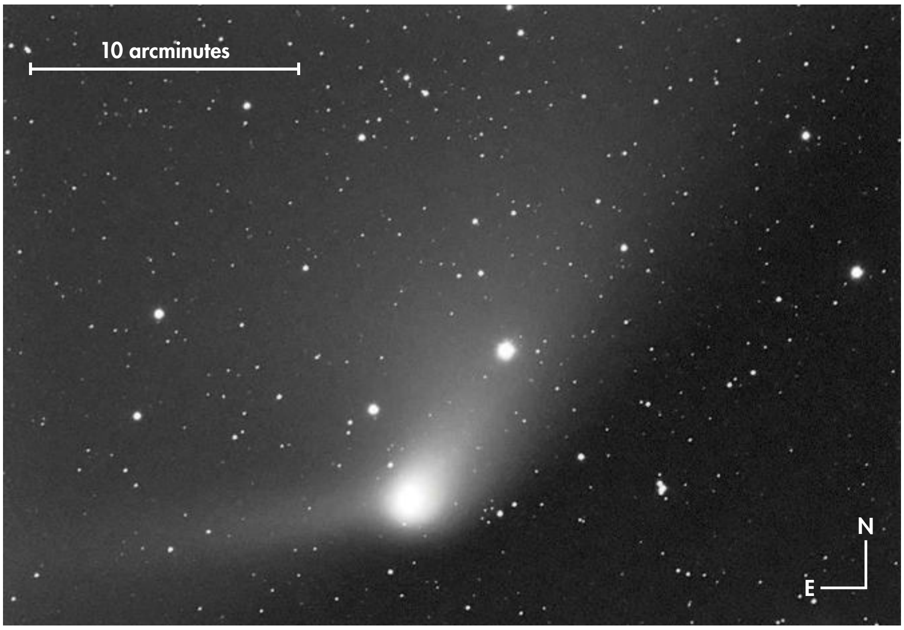
"The Comet section produces a newsletter, *The Comet's Tale*, which can be downloaded from our website (britastro.org) and there are often items of interest to comet observers in the BAA Journal."

PETE LAWRENCE X 4

PROJECT 1

Comet photography

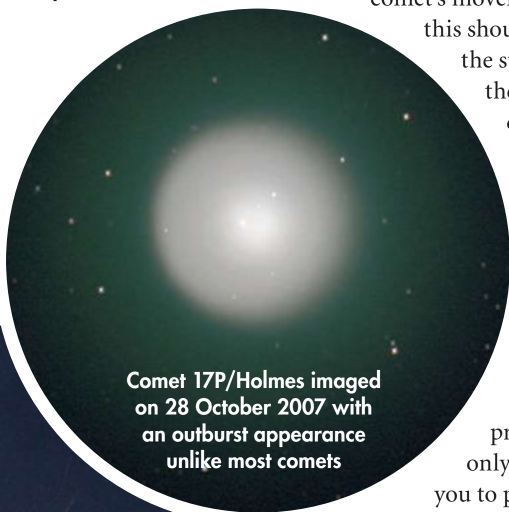
How to produce images of sharp comets against sharp background stars



▲ C/2011 L4 PanSTARRS imaged on 3 May 2013. Seven 120-second exposures using a Starlight Xpress SHV-H9 CCD camera were processed to show sharp stars and a sharp comet

Your images can contribute to science by helping to document how a comet evolves over time. A good and surprising example was comet 17P/Holmes, which underwent a massive outburst back in 2007, appearing over half a million times brighter than expected. The outburst was accompanied by many changes in the comet's appearance that, when viewed in sequence, described the fascinating and unusual evolution of this amazing object.

The ill-fated comet C/2012 S1 ISON, which disintegrated shortly after this image was taken on 22 November 2013



Comet 17P/Holmes imaged on 28 October 2007 with an outburst appearance unlike most comets

Many different camera setups are suitable for imaging comets. Brighter comets make ideal targets for general photographic equipment, such as a DSLR fitted with a standard lens. Dimmer targets up the ante, requiring more sensitive equipment, typically a cooled CCD camera fitted to a telescope.

Comets move, often quite rapidly, relative to the background stars. For this reason, mid-range ISOs and relatively short exposures between 30–120 seconds are normally used. Dark and flat-field calibration is also essential to obtain the best and most accurate results. When it comes to registration-stacking, doing it on the stars will result in a blurred comet, while registering on the comet will produce trailing stars.

More sophisticated techniques involve registering on the comet and rejecting maximum pixel values between shots. If a comet's movement is sufficient, this should remove most of the stars. Subtracting the resulting comet-only image from the original star and comet frames will isolate the star-field. Stacking the star-only images and recombining them with the processed comet-only image then allows you to produce a shot of a detailed comet against the background of a sharp star-field.

Submissions to organisations such as the BAA often require image filenames to be formatted in a certain way. For the BAA, the format cometname_yyyymmdd_hhmm_observer is preferred, where 'cometname' is the identifier of the comet, 'yyyymmdd' and 'hhmm' are the date and time of the image and 'observer' is the imager's name or initials. Scale and orientation should also be included on the image with the preferred orientation being north up and east to the left.

PROJECT 2

Introduction to comet astrometry

Your images can help pinpoint comets and trace their paths through the Solar System

Astrometry is the science of determining the precise positions and movements of astronomical bodies. This is especially important for small Solar System bodies such as comets where such measurements help refine the object's orbit.

The high accuracy required for the measurements places certain demands on your images. The world-wide clearing house for submission of positional comet measurements is the International Astronomical Union's Minor Planet Center (MPC), which maintains a detailed Guide to Minor Body Astrometry at www.minorplanetcenter.net/iau/info/astrometry.html.

▲ A cooled astronomical CCD camera, ideal for comet astrometry

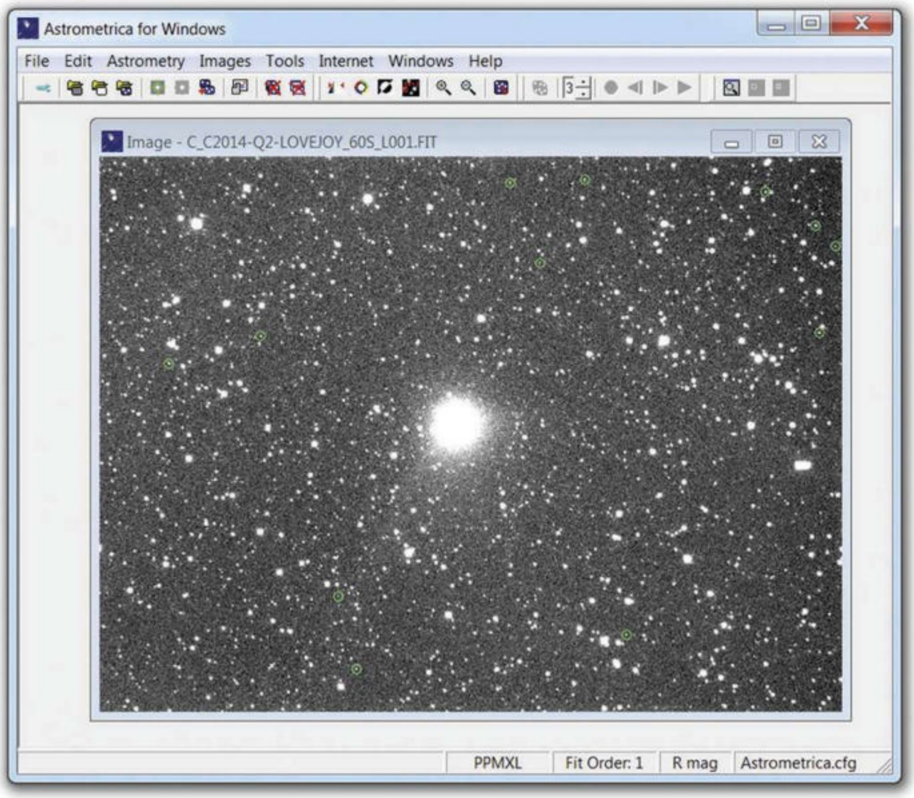
Comet astrometry is normally done using a CCD camera and an image scale of two arcseconds per pixel. A scale of three arcseconds per pixel is considered the lower limit of quality. You can work out your setup's image scale using this formula: Image scale (in arcseconds/pixel) = (206.3 x pixel size in microns) / focal length in millimetres.

To carry out astrometry on a comet requires the reduction of an image containing the comet. This entails identifying the star field (a process known as 'plate-solving'), determining the position of as many stars as possible from permitted catalogues and finally working out the position of the comet using a least-squares plate-constants (LSPC) solution. This process must be done using software; manual reductions are not considered accurate enough.

▲ Ideally, astrometric images should show the central core of the comet, avoiding overexposure in the comet's head

Submissions to the MPC must follow strict formatting guidelines. Two submission forms are permitted: one for permanent observatories and one for roving observations. A permanent observatory will ultimately be given a three-digit MPC observatory code, while a roving observation will use the observatory code 247 along with extra data to precisely identify where the observation was made on Earth's surface. There are full details on how to obtain a permanent observatory code from the MPC in the Guide to Minor Body Astrometry mentioned earlier.

The astrometry software listed under recommended software will produce the required MPC submission format automatically. Further information about permanent observatory submissions can be seen at minorplanetcenter.net/iau/info/OpticalObs.html and for roving observations at minorplanetcenter.net/iau/info/RovingObs.html.



▲ Astrometrica software is a popular choice for astrometric measurements

ALL PICTURES: PETE LAWRENCE

PROJECT 3

Introduction to comet photometry

Measure a comet's brightness by calibrating and stacking your images

▲ One issue when measuring a comet's brightness in an interactive program such as MaximDL is determining an 'aperture' size to encompass the entire comet head

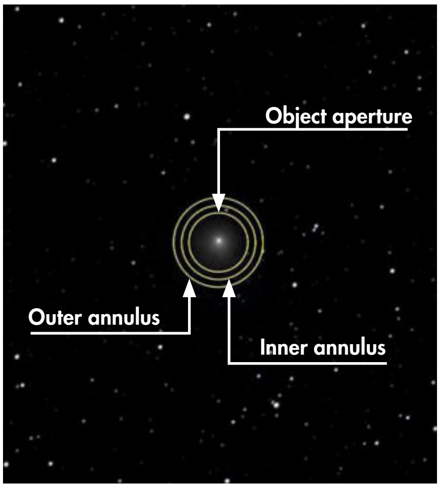
Photometry is the science of measuring an object's brightness and there are a number of important aspects to consider when performing photometric measurements on comets. Firstly, images need to be pre-calibrated using matching flat and dark frames. As sky brightness makes a contribution to the comet's brightness, this too needs to be measured. Some programs, such as MaximDL, perform this function using an aperture and an annulus. The aperture measures the comet's brightness while the annulus is used to measure the background sky brightness.

The BAA program Comphot (see Hardware & Software, p72) can be used to perform photometry on comet images. This requires two FITS images as a source, one stacked on the background stars and the other on the comet. This is a command line program normally initiated by typing: comphot offset.fit fixed.fit x y

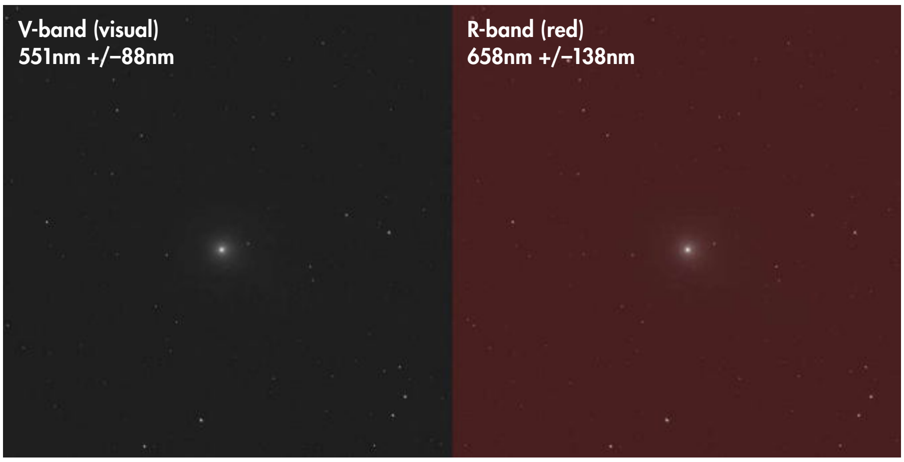
Here offset.fit is the image stacked on the comet, and fixed.fit is the image stacked on the stars. Both files are in the FITS (Flexible Image Transport System) file format, a technical format preferred for astrometry and photometry.

The x and y values are the coordinates of the comet's coma centre and can be derived by using a position-measuring program such as Astrometrica. The UCAC-4 star catalogue is recommended for positional measurements. As the coma contains reflected sunlight as well as light generated by excited coma atoms and molecules, specialist photometric filters are normally used for imaging. If you're using FITS images from a CCD without a filter, R-band magnitude values should be selected in Astrometrica. If using a green filter, V-band magnitudes should be used. An R-band filter is a red filter typically centred on 658nm, while the V-band filter is centred on the visual wavelength at 551nm.

The Comphot software is capable of outputting its measured findings in the correct format required by the International Comet Quarterly (ICQ). Like the MPC submissions mentioned in project 2, the ICQ requires that this data follows a strict submission format. Details of this format are available from www.icq.eps.harvard.edu/ICQFormat.html.



▲ An object aperture should contain the comet's head. The inner annulus is a gap, adjusted under software to ideally contain no stars



▲ Common photometric filters used for comets are V- and R-band filters. They help to isolate reflected sunlight from excitation radiation from within the coma

SKILLS

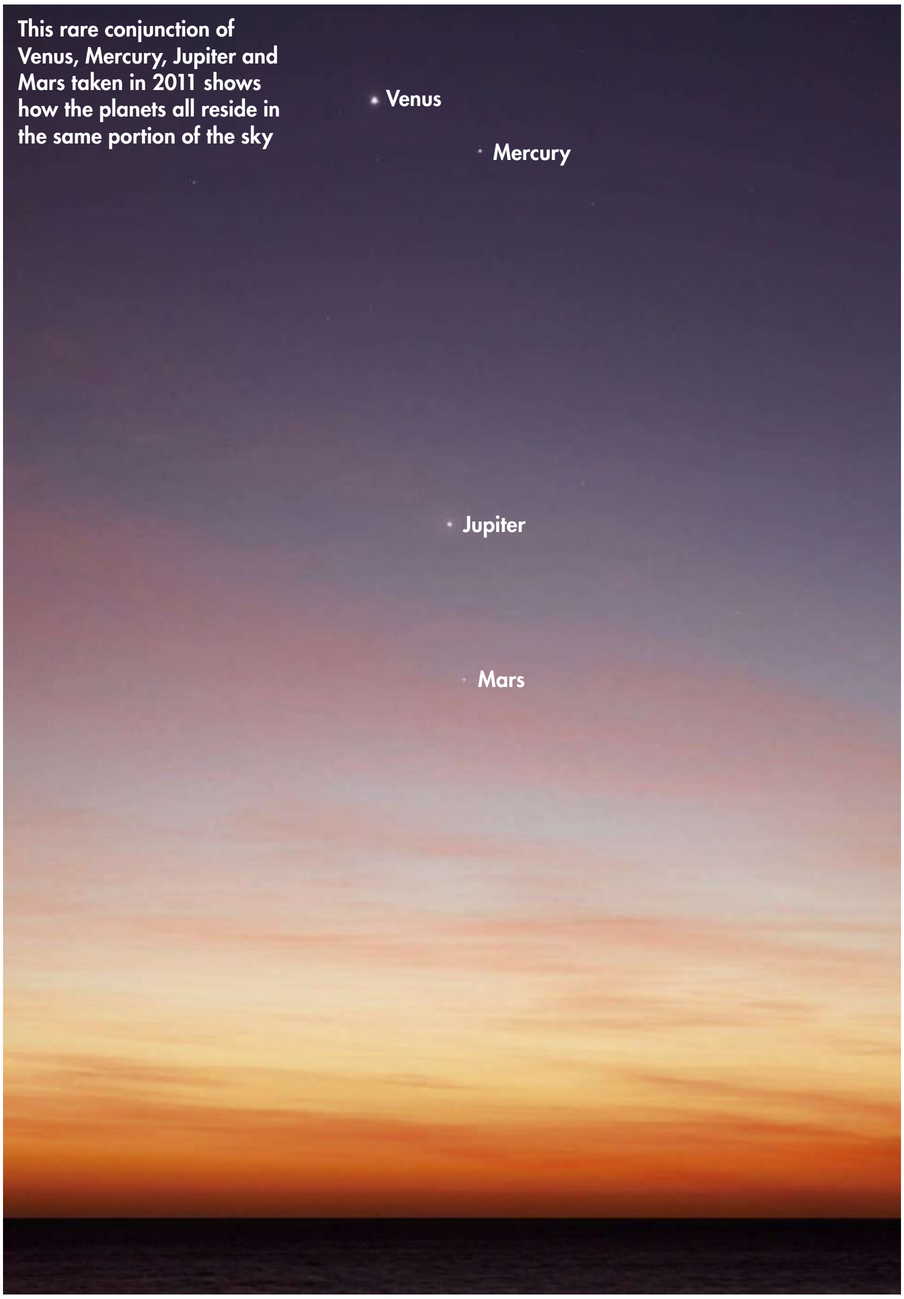
Brush up on your astronomy prowess with our team of experts

The Guide

With **Scott Levine**

Finding the planets without a map

It's simpler than you think – all you need are your powers of deduction



This rare conjunction of Venus, Mercury, Jupiter and Mars taken in 2011 shows how the planets all reside in the same portion of the sky

STOCKTREK IMAGES INC /ALAMY STOCK PHOTO, PAUL WOOTTON X 2

At the risk of pointing out something obvious, there aren't any labels on the sky. If you've just started stargazing it may seem hard to find and identify the Solar System's planets using your naked eye, without a planetarium to lend a hand, amidst all of the stars you can see. This is a useful skill to have, though, and it's not as difficult to master as it might seem.

The first thing you need to do is find the ecliptic, the imaginary line that marks the path the Sun takes across the sky (see box). Since all of the Solar System's major planets orbit the Sun in roughly the same plane, the ecliptic also marks the path of the planets. You'll always find all of the planets near that line. Is it bright, but on the wrong side of the sky to the ecliptic? Then it can't be a planet.

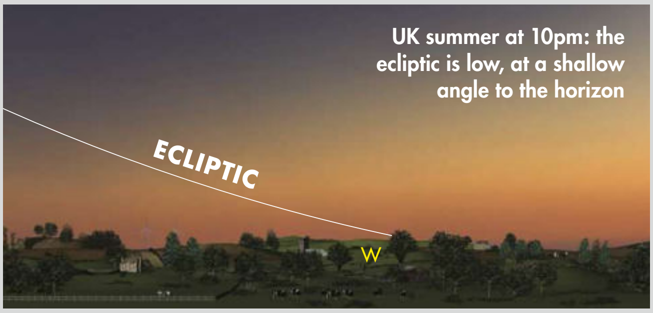
Once you know *roughly* where to look, you can work out which objects are planets.

In the same way that a small tree outside your window looks bigger than a larger tree on a distant hillside, planets look bigger than the much larger and much more distant stars. This apparent size difference gives them a subtle disc shape, which often becomes easier to see the more you look for it. Also, because their light comes to us from many points – not just one as starlight does – they usually don't appear to twinkle. Many planets have distinct hues; in some cases, they can shine much brighter than any star.

Mercury and Venus are inferior planets. That doesn't mean they are uninteresting, only that they orbit closer to the Sun than Earth does. From our perspective, they are always relatively close to the Sun in the sky. Venus is never more than 47° away from it, which is about the width of five fists held out at arm's length. Mercury is closer still, never more than 28° away. This means they

WHERE IS THE ECLIPTIC?

To find the ecliptic, make a note of the Sun as it crosses the sky – pay attention to where it rises and sets, and where it is during the day. How high above the trees and the rooftops across the street is it, for example? Once you have a feel for the path the Sun travels on during the day, use your imagination to try to map its path onto the night-time sky. Keep an eye on the Moon, too. Its orbit around Earth tilts by about 5° compared to the ecliptic. That means the ecliptic is always within 5° of the Moon. That's about the width of three of your fingers held up at the end of your outstretched arm. Finally, remember that the ecliptic does not remain in the same place year round, something you can imagine by remembering that the Sun gets higher in the sky during the summer months than it does in the winter.



always rise shortly before the Sun or set shortly after it. They'll never soar high overhead late at night.

Since Mercury is very small, speedy, and close to the Sun, it's particularly difficult to see. It's only visible for a short time, most often in glowing twilight, so you'll need to be quick to spot it. As challenging as it is, Mercury is bright enough to stand boldly against skies too bright for most stars. If you see something yellowish staring back at you through the dawn or dusk, there's a chance it could be Mercury. Fellow inferior planet Venus is a stark contrast: a beautiful white colour and bright to the point of being unmistakable, its peak magnitude –4.4.

The superior planets are those that orbit farther from the Sun than Earth. They're not 'tied' to the Sun from our perspective and can be anywhere along the ecliptic. Red-orange Mars (peak magnitude –2.9), whitish-orange Jupiter (mag. –2.9), and understated yellow Saturn (mag. +4.3) are all visible to the naked eye. Uranus and Neptune are not. Uranus has a magnitude of mag. +5.7, hovering on the threshold of naked-eye visibility, but you'd need impeccable eyesight and pristine skies to stand a chance of spotting it. Neptune (mag. +7.8) is simply too dim to see without binoculars.

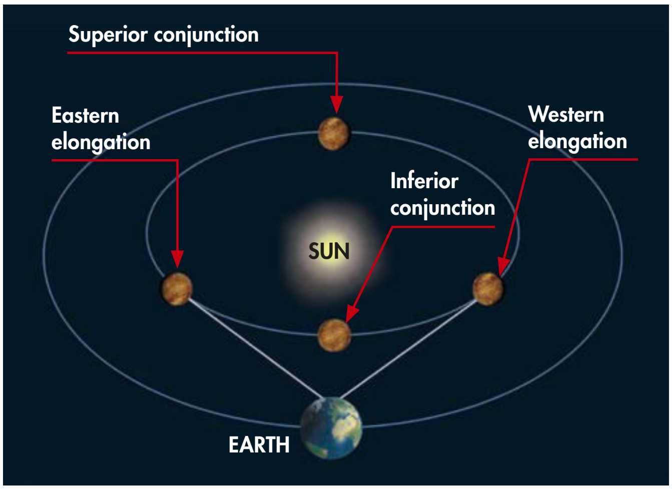
But is it even up?

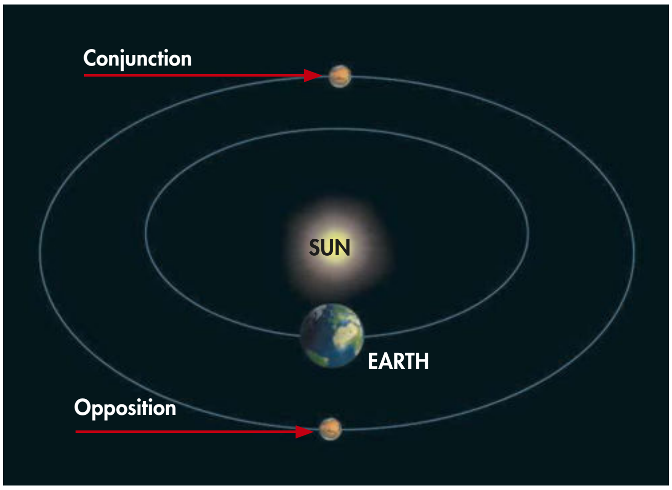
All of this said, there are times when finding the planets isn't easy. For one thing, even the superior planets may not be above the horizon all night long. They can all disappear in the daylight sky, or may be stuck lingering just above the horizon. From time to time, the planets are in conjunction with the Sun and are lost from view completely.

Nor do all planets shine at their peak magnitudes at all times – that depends on where they are in their orbits. Superior planets tend to be brightest around opposition, when they are on the opposite side of the sky to the Sun. With the inferior planets, the situation is more complex – they are brightest in certain crescent phases, but set relatively soon after (or rise only briefly before) the Sun. The gap between the Sun setting or rising and Mercury/Venus doing the same is greatest at the points of greatest elongation, but they are dimmer on these occasions.

If you think you have found a planet, but you're really not sure, keep an eye on it for a few nights. Remember, the word planet comes from the Greek word for 'wanderer'. All of the planets move, or wander, relative to the background stars. From night to night, you'll see them in a different position, but the stars themselves will stay fixed to each other. Of course, this effect is more pronounced the closer the planet is to Earth: Mars positively races across the sky compared to much more serene Saturn. But with a little bit of practice, you'll be able to find them. Ⓢ

SCOTT LEVINE is an amateur astronomer and astrophotographer





▲ The major orbital points of the inferior planets (left) and superior planets (right); where a planet is in its orbit affects its brightness and disc size

With
Paul Abel

How to...

Estimate the brightness of variable stars

Master the Pogson Step and you'll be able calculate with confidence

Algol's variability has made it famous – representing the eye of the Gorgon Medusa, it's also known as the Winking Demon

TOOLS AND MATERIALS

STAR CHARTS
You need to get these from the BAA or AAVSO as they will indicate suitable comparison stars. Your comparison stars can't be variables too.

TOOLS
A selection of eyepieces, offering low to high power; you'll need to use different comparison stars over time.

MATERIALS
Red light torch, clipboard and paper for use at the telescope, sturdy notebook for your written-up notes.

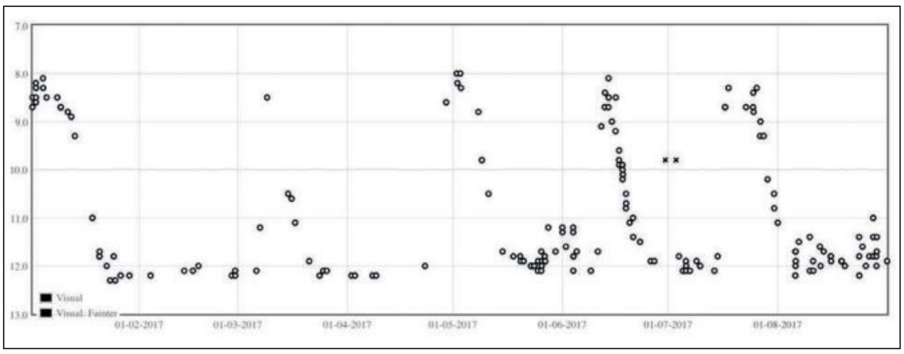
We often think of the stars in the night sky as unchanging over the span of human lifetimes, but in fact a large proportion of them change over the course of weeks, days and even hours. These are variable stars, exciting bodies that are essential in helping astronomers understand stellar evolution.

There are many reasons why stars vary. Some are red giants at the end of their lives that are expanding and contracting, causing them to slowly brighten and fade; these are known as pulsating variables – Mira in Cetus was one of the first to be identified. In an eclipsing binary system, the variation is due to one star passing in front of (or behind) another. Algol in Perseus is a splendid example and the change in magnitude is noticeable after just a few hours.

Then there are eruptive variables, where the change in brightness is due to material from one star being transferred to the surface of another, often via a stream of hot gas that coalesces into an accretion disc. It is believed temperature changes in the disc are responsible for the fluctuation in brightness. Such stars, SS Cygni being one example, can suddenly brighten from mag. +12.0 to mag. +8.0 in just a few hours.

There are many variable stars in the sky, and all require long-term study. With professional telescope time at a premium, it is not surprising that the vast amount of variable star observations still come from amateur astronomers. The main aim is to collect magnitude estimates of each star, which can be plotted and reveal long-term changes over time. The resulting chart is called a 'light curve'.

The Variable Star Section of the British Astronomical Association (BAA; **www.britastro.org**) and the American Association of Variable Star Observers (AAVSO; **www.aavso.org**) are actively engaged in the long-term, systematic study of variables. They provide the astrophysics community with much needed data and amateurs with great resources for reporting observations, including star charts and online forms. ▸



▲ Plotting magnitude estimates creates a 'light curve' that tracks a star's variability over time

▸ You'll also find some helpful beginner articles on these sites, as well as suggestions for variables you might want to start with.

Variable star observation doesn't require any special equipment. Observations can be made with the naked eye as well as with binoculars or a telescope, and moreover they can be made visually, without any photographic kit. Making a magnitude estimate is usually done by comparing the brightness of the variable with two comparison stars, one slightly brighter and one slight fainter. For accuracy, the Pogson Step Method uses increments of 0.1 (one-tenth of a magnitude) for magnitude estimates. What follows is a real-life example of how it works.

Falling into step

On 31 August 2017 at 22:06 UT, we observed the star Chi Cygni and two comparison stars: Star A at mag. +6.4 and Star B at mag. +5.0. Compared with A, we found Chi Cygni to be about six times brighter on the Pogson scale, so recorded it as 'A+6'. To work out the magnitude we subtract 0.6 from 6.4 (the magnitude of A), this gives an estimated magnitude of +5.8.

Comparing with star B, we found it to be about five times fainter, and so we recorded 'B-5'. To work out the magnitude we must now add 0.5 to the magnitude of B, this gives us +5.5. We now take the average of these two values and this gives an estimated magnitude of +5.65, which can be rounded up to +5.7. In some cases, you might find only one comparison star can be used, in which case you would just record one estimate. Our step by step section shows us in action estimating SS Cygni as an example.

Unlike planetary work, you don't need to worry about good seeing conditions when observing variable stars. Don't be afraid to experiment with different eyepieces, as you might find some comparison stars are some distance away from your variable. What's really important that you report your observations. Use the online forms on the BAA and AAVSO websites to submit your magnitude estimates; you can then see your observations in the light curves for these stars, and your data can be used by professional scientists.

Variable star observing can be addictive, and it's great to be making observations which really count. We're sure after a few months, you'll soon find yourself wondering 'what's my star doing tonight?'

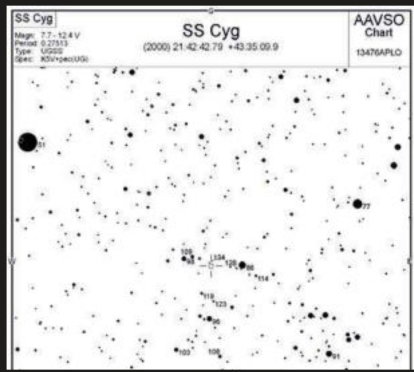
PAUL ABEL is an astronomer based at the University of Leicester

PAUL ABEL X6

STEP BY STEP

STEP 1

Make sure you have all your star charts printed out beforehand. You will need to make sure your eyes are dark adapted before you start observing, and this typically takes 20-30 minutes. Use a red light torch to preserve your night vision.

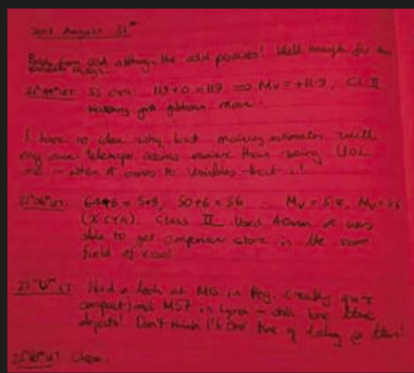


STEP 2

Locate your variable star. Use a star chart to make sure you have identified the comparison stars and the variable correctly – don't be disheartened if this takes a while, especially if you're not familiar with this part of the sky.

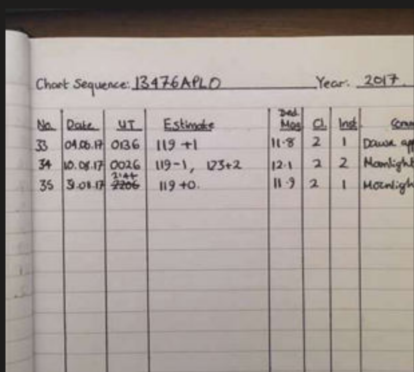
STEP 3

When you've selected your comparison stars and have identified the variable star, make the magnitude estimate by comparing their brightnesses. Do this several times and average the result to take out any bias to ensure as accurate an estimate as possible.



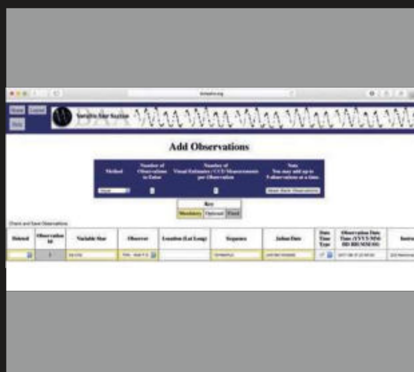
STEP 4

Record your estimate along with date, time (UT) and telescope. Record any conditions that affect your observing: for example, a bright Moon may influence your magnitude estimate. Mist or haze can also make stars appear fainter than they are.



STEP 5

Once indoors, transfer all the information from Step 4 into a more permanent log book or a spreadsheet. It's useful to keep a log with records for each star, so all the observations are in one place. If you keep it on a spreadsheet, keep your data backed up.



STEP 6

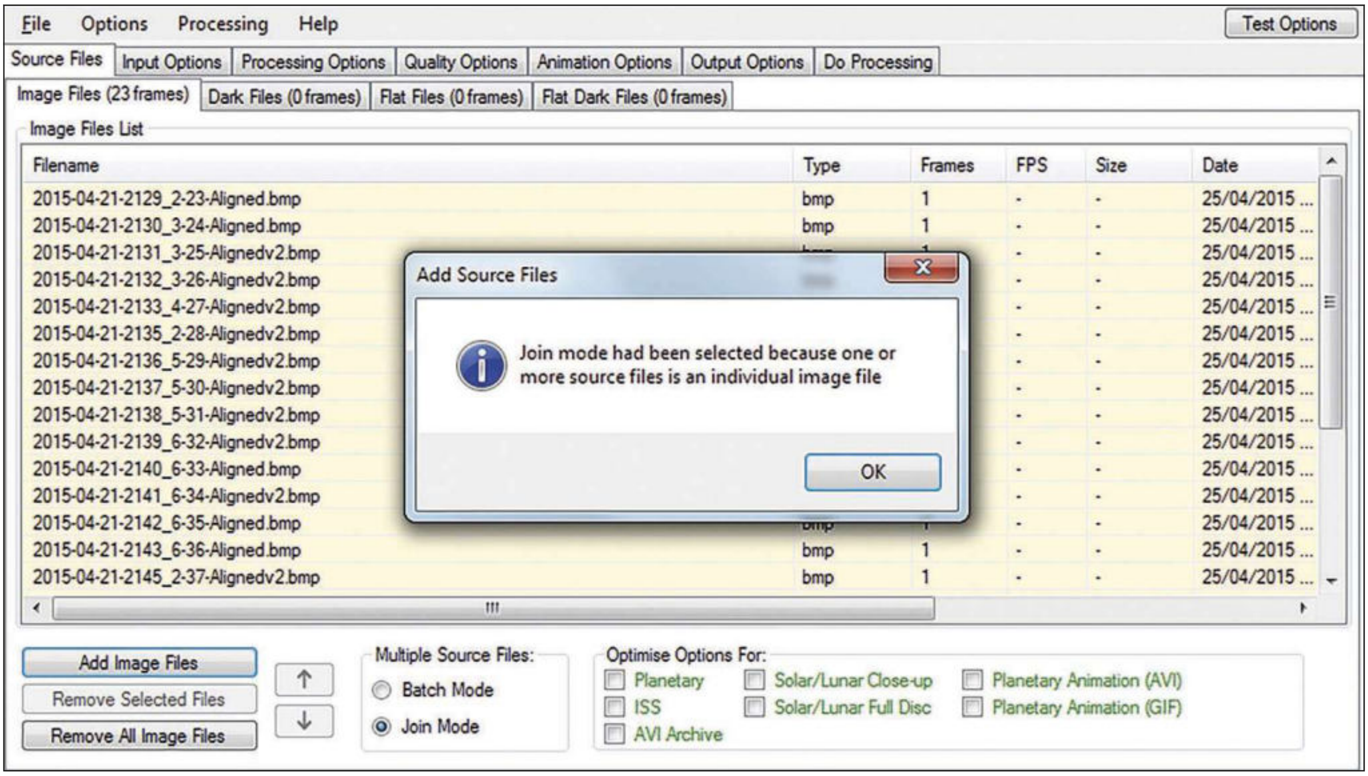
Report your observations to the BAA and AAVSO; you can upload each individually or in bulk. By doing so you can provide valuable data and it is incredibly satisfying knowing you have made a real contribution to science.

Image PROCESSING

With
Martin Lewis

Animations and surface stabilisations in PIPP

Build a sequence of shots to create a video of your favourite astronomical target



▲ Select the frames you want to use to make your animation in the Source Files tab; doing so brings up this dialog box to merge them together

We're taking another look at the freeware astro video processing program PIPP (**https://sites.google.com/site/astropipp**), the key features of which we covered in our August and October 2017 issues. In our previous instalments, we discussed some of its basic editing functions; this month, we're looking at how to combine your stills together into an animation and stabilise surface features on videos of the Sun and the Moon.

PIPP is able to convert video between a number of formats and readily split videos into individual frames. Conversion the other way around – that is, taking frames and stitching them together to make an animation – is just as easy. You might want to do this to show the evolution of a solar prominence, the rotation of a planet or the movement of its moons.

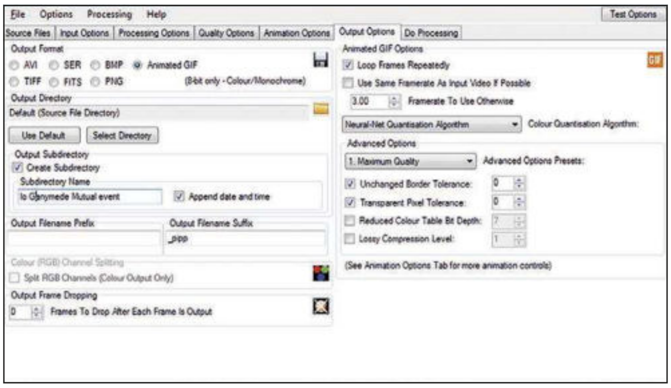
The first step in making an animation is to add your set of frames to the list in the **Source Files** tab using the **Add Image Files** button. When you select multiple frames, the **Join** function dialog box will pop up. Click Ok to link all the frames together. If the files aren't in the correct order for the animation, you can shuffle them by clicking on the column headers – name, date and so on. Alternatively, you can select individual frames in the list and move them around using the up/down buttons.

The next step is to go to the **Output Options** tab and decide if you want to have a GIF or AVI animation. In most cases GIF is most appropriate, as they allow you to set the animation to repeat indefinitely by ticking **Loop Frames Repeatedly**. On this tab you can also set the GIF's quality and the desired frame rate. Incidentally, the frame rate option can be used for any video, allowing for slower or faster playback speed than the original recording – a useful function, especially for creating timelapses.

Options and adjustments

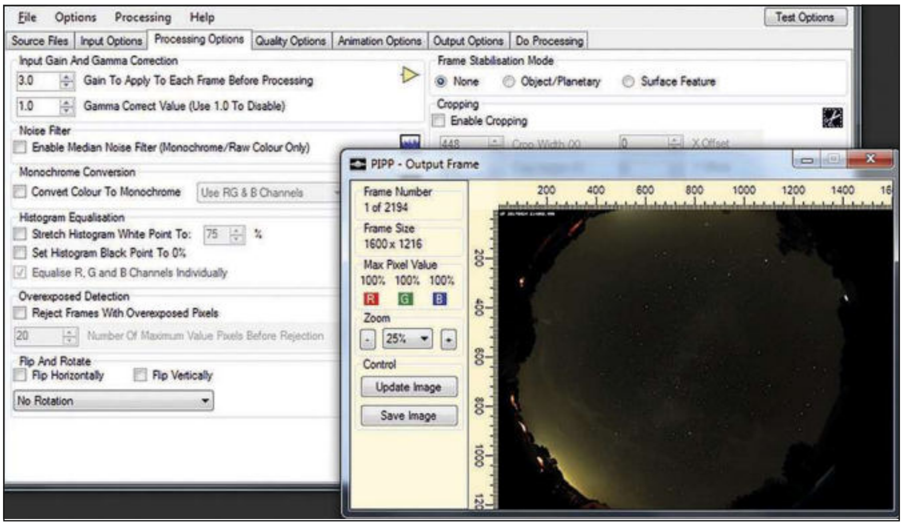
Other animation related options are available on the **Animation Options** tab, and these include the option to introduce pauses at start or end of the sequence, and to determine forward and reverse playing. Once you have set all the options use the ▸

ALL PICTURES: MARTIN LEWIS



▲ You can set frame rate and GIF looping on the Output Options tab

▲ Animation options include adding pauses and playback direction



▲ PIPP also allows you to adjust gain and gamma – in this case for an all-sky timelapse

▸ Start button in **Do Processing** tab to then create your animation.

Another valuable PIPP feature allows you to adjust the gain (brightness) and gamma (contrast) of all the frames of your recorded video. This is great for bringing out details in footage such as all-sky camera timelapses or overly dark lunar drift videos. The gain and gamma controls are found in the top-left of the **Processing Options** tab. To preview their effect on a frame, use the **Test Options** button at the upper-right corner of PIPP.

PIPP is adept at successfully aligning and stabilising lunar and solar videos so that difficult and jumpy videos can then work successfully in stacking programs such as AutoStakkert! and RegiStax. It will cope well with sudden positional changes due to pauses in the recording or sudden wind buffeting that might cause issues for the stacking programs without editing.

To align a solar or lunar video, click on **Surface Features** in the **Processing Options** tab and select **Surface Feature Tracking** and **Surface Stabilisation**. An 'anchor feature box' (AFB) will automatically appear in the preview image which will be the first frame of the video. You should drag the middle of the AFB onto a high-contrast feature such as a crater or sunspot and resize it by dragging the corners of the AFB until it fits the outline of the chosen feature.

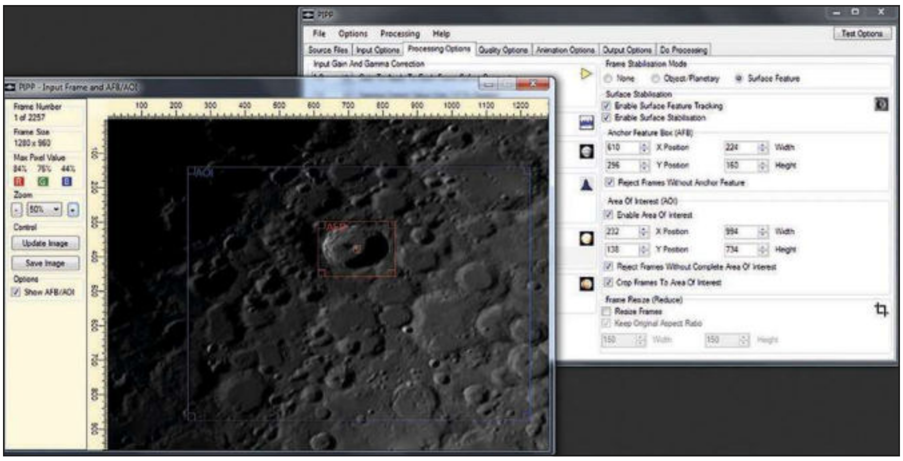
Smoothing out wrinkles

A nice refinement for lunar and solar videos is that you can also set an 'area of interest' (AOI) for the video by clicking on the AOI box. This produces a box that every frame must contain, or else the frame is rejected. The use of an AOI prevents issues where the final stack might become a patchwork of dissimilar areas around the edge, each where different numbers of frames have contributed to them. The different regions require different amounts of processing and this can create annoying artefacts at their junctions.

You can position and resize the AOI box just like the AFB box, with the handles or via numerical entry. Do be aware that if the box is made too large you might find there are hardly any frames left which have not been rejected for not containing the AOI.

A final feature that may be useful is PIPP's ability to perform lossless compression using the ULRG codec available on the **Output Options** tab. This can be used for archiving purposes and reduces file sizes by about 30 per cent. Don't worry, ULRG files can still be read by RegiStax and AutoStakkert!, should you want to reprocess them at a later date. S

MARTIN LEWIS is a Solar System astro imager and telescope builder



▲ Setting AFBs (red) and AOIs (blue) will help with frame alignment and reduce stacking artefacts

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Scope DOCTOR

With Steve Richards

Our equipment specialist cures your optical ailments and technical maladies

I have a portable Celestron NexStar 4SE to make the most of dark skies on holiday. Would an Altair Astro GPCAM2 290C colour camera go well with it, and should I consider a wedge?

TREVOR RATHBONE

The Celestron NexStar 4SE is a 102mm Maksutov-Cassegrain telescope with a focal length of 1,325mm, mounted on a Go-To altaz mount. It's ideal for observing and imaging the Moon and planets but it will also work well for observing many deep-sky objects.

The Altair Astro GPCAM2 290C is a one-shot colour camera with a frame rate of 17.5 FPS at full resolution and up to 56 FPS with a region of interest (ROI) at 320 x 240 resolution. But it's also capable of capturing long exposures of over 15 minutes. This range of exposure lengths mkes it possible to capture both Solar System objects and many deep-sky objects.

Attached to the 4SE, the 290C will capture a field of view of 14.6 arcminutes by 8.2 arcminutes. The average angular size of the full Moon is 31 arcminutes, so a single frame from this combination won't capture the whole Moon. A mosaic made up of six tiles, however, would produce a magnificent high-resolution image of the quarter Moon.

Many deep-sky objects, such as globular clusters, planetary nebulae and binary stars, would be well within reach of this combination providing you stick to the brightest examples to keep the exposures short.

Adding a wedge would certainly help and you can use the built-in 'Wedge Align' procedure for polar alignment but the mount's tracking capabilities would make long exposures challenging.

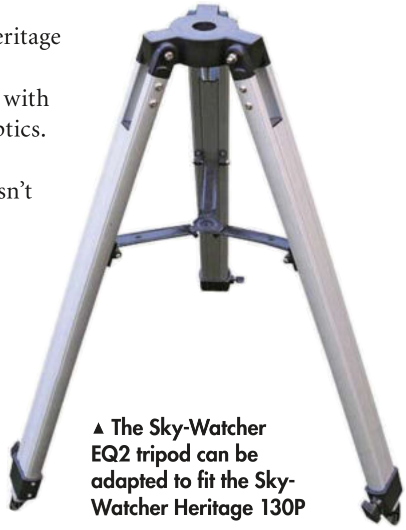
◂ Altair Astro's GPCAM2 290C is a one-shot-colour camera

WWW.SECRETSTUDIO.NET, STEVE RICHARDS

I bought a table-top Sky-Watcher Heritage 130P telescope, but now struggle to bend down to look through it. Should I get a new mount or should I consider a new scope altogether?

PAUL SHIELS

The Sky-Watcher Heritage 130P is an excellent Dobsonian reflector with surprisingly good optics. Unfortunately, the Flextube design doesn't lend itself easily to a different mounting arrangement so if you're unable to raise the whole altaz mount onto a higher table or other platform, a new telescope and mount could make good sense. The Sky-Watcher Explorer-130PS AZ Pronto or possibly the Celestron AstroMaster 130EQ would be suitable choices.



▴ The Sky-Watcher EQ2 tripod can be adapted to fit the Sky-Watcher Heritage 130P

There is, however, a rather simple way to resolve this issue if you are prepared to do a little DIY. If you buy a Sky-Watcher EQ2 mount and tripod set, you could remove the EQ2 mount leaving you with a height-adjustable lightweight tripod that has a flat top. If you then got a longer central mounting bolt to replace the standard one, you could use the longer bolt to attach your existing Dobsonian base to the top of the tripod.

STEVE'S TOP TIP

What are the main advantages of colour and mono CCD cameras?

The advantage of a one-shot colour camera is that full-colour images can be captured during short imaging sessions – a real bonus under cloudy UK skies – plus you don't have the additional cost of filters and a filter wheel.

The advantage of a mono camera and filters is that ultimately they will produce higher quality images. However, you need have to collect a minimum of three sets of filtered data (red, green and blue), and preferably luminance as well, to produce a colour image. Both types produce their best images when you take and stack multiple frames.

Steve Richards is a keen astro imager and an astronomy equipment expert

Email your queries to scopedoctor@skyatnightmagazine.com

BBC Sky at Night MAGAZINE

Reviews

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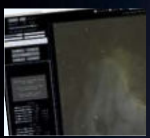
Each category is given a mark out of five stars according to how well it performs. The ratings are:

★★★★★ Outstanding
★★★★★ Very good
★★★★★ Good
★★★★★ Average
★★★★★ Poor/Avoid

This month's reviews

FIRST LIGHT



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FIRST LIGHT

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Sky-Watcher SkyMax-127 with AZ-GTi Wi-Fi mount

Find your viewing targets with the help of wireless computer control

WORDS: PAUL MONEY

VITAL STATS

- **Price** £529
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- **Mount** AZ-GTi Wi-Fi Go-To
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- **Tracking rates** Sidereal, lunar, solar, alignment free
- **Tripod** Adjustable legs with accessory tray
- **Extras** Red-dot finder, 25mm & 10mm eyepieces (1.25-inch fit), star diagonal
- **Weight** 7.45kg
- **Supplier** Optical Vision
- **www.**opticalvision.co.uk
- **Tel** 01359 244200

Wirelessly controlled telescopes that can be operated using a smartphone are becoming more popular, and the latest addition to this stable is Sky-Watcher's AZ-GTi-mounted SkyMax-127.

The telescope is a 127mm (5-inch) Maksutov – a compound telescope with a primary mirror and a front corrector plate that includes a silvered secondary mirror. It has a focal length of 1,500mm, giving a focal ratio of f/11.8, so it's considered a 'slow' system – ideal for lunar and planetary observing, but capable of satisfactory deep-sky views too.

The AZ-GTi is a Wi-Fi-controlled Go-To mount of altaz design that's easy to assemble and comes with an adjustable aluminium tripod and an accessory tray. A power supply is required from either eight AA batteries or a power tank – we tried both for this test and had no trouble with either.

The mount is designed to be controlled with a smartphone or tablet. To do so, you need to download the free SynScan app, which is available for iOS and Android. It is not a planetarium program, but offers a lot of functionality. When powered up the mount provides its own Wi-Fi network, which you connect to via the SynScan app. Once connected the alignment icon becomes active. The first time you start it up, the app will also ask for permission to access your location, which it uses to determine basic details.

SKY SAYS...
Both of the SkyMax-127's eyepieces can reveal fine lunar detail, such as domes and rilles

Accuracy and alignment

There are two alignment options: two star and north/level alignment, and both gave good results, usually placing our targets in the field of view of the 25mm eyepiece. Using the 10mm eyepiece improved accuracy for better alignment. There's also an option to align on any target once you've slewed to it via the Go-To option, which improves accuracy for other targets nearby.

The app has two options for accessing targets, Star and Deep Sky – bizarrely Solar System objects ▸

WIRELESS CONTROL

The SynScan app proved easy to navigate and use. The main screen is split, so that you have various options (alignment, target type, utility, user objects and settings) in the top two-thirds of the screen, while the bottom third is given over to a control pad for manual slewing and performing your initial alignment. Slewing speed can be adjusted with the small arrow icons, with the speed change displayed at the centre. It quickly became second nature to select and slew to a target using this control method.

For most purposes the database of targets is good, but if you'd prefer to use a planetarium app to control the system your options are limited. At the time of writing only Sky Safari Plus and Pro are supported. Note: Apple users need two devices to connect Sky Safari – an iPhone *and* an iPad, for example – as iOS on a single device can't run both the SynScan and Sky Safari Plus/Pro apps simultaneously. Android users can connect through a single device.

▲ You can set the SynScan app to display in red light to retain your night vision

WWW.THESECRETSTUDIO.NET X 3, PAUL MONEY X 2

PORTS

The AZ-GTi mount has three ports: a snap port for connecting and controlling a camera, a power connector for an external supply (such as a power tank) and a port for an optional SynScan AZ hand controller. There's also a red LED to indicate the operational state of the mount.

ACCESSORIES

The red-dot finder is basic but worked well for aiming the telescope, especially during alignment. A 90° star diagonal is included along with two eyepieces, 25mm and 10mm, which provide magnifications of 60x and 150x. The eyepieces gave good views of our targets, with the Moon a highlight.

CLUTCHES

The mount features two clutches for azimuth and altitude adjustment/ tensioning. The clutches can be slightly loosened to allow for manual movement of the mount without losing Go-To alignment, a process known as 'freedom find'.

TRIPOD & EXTENSION

The tripod has telescopic aluminium legs that can be extended and locked to any length, and provide a sturdy base. The tripod extension is a welcome extra for when a target is high in the sky, as in this scenario the SkyMax-127's eyepiece can be quite low to view through.

FIRST LIGHT

SKY SAYS…
Now add these:
1. 7Ah powertank
2. Planetary & lunar filter set
3. Red LED torch

▸ are included under Star. Choose Star and your targets include the Solar System (planets, Sun and Moon) named stars and double stars. Under the Deep Sky menu you have a named objects icon or can select from the Messier, Caldwell, NGC or IC catalogues. There's also a point and slew option, which we found to be great fun – the mount slews to the approximate location you're pointing at and then offers you a selection of targets to home in on.

Control options

The app's settings give you the option to have your device display a black background with red text to preserve your night vision but if you wish to enter a number for any of the deep-sky categories then the pop up screen is white – something we hope will be addressed in a future update.

You don't have to use the app, though. The mount can be operated with a SynScan hand controller and you can download an ASCOM driver from the Sky-Watcher website and control the scope with a computer.

We took a tour of various targets, taking in Uranus and Neptune, open cluster M45 in Taurus and the Double Cluster in Perseus, the latter just fitting in the view using the 25mm eyepiece. The Dumbbell Nebula in Vulpecula had a nice glow to it, while the Ring Nebula in Lyra lived up to its name when glimpsed through the 10mm eyepiece. On another night we saw the Moon was replete with cratered detail along the terminator using both eyepieces, and each one is certainly capable of revealing fine detail, such as lunar domes and rilles.

This is a fun system to use. Although there is an option to connect a SynScan hand controller, to get the most of this setup its worth downloading the SynScan app for your smartphone. The SkyMax-127 feels like the future of telescope control, certainly for anyone that likes technology and is just beginning their exploration of the sky. Ⓢ

▲ The Moon taken with a Canon EOS 50D DSLR, single image 1/100th of a second at ISO 100

◂ Albireo, Canon EOS 50D DSLR, five-second exposure at ISO 3200, slight processing with PaintShop Pro X9

OPTICS

The SkyMax-127 is a Maksutov telescope, meaning it contains a primary mirror and a corrector plate, with the secondary mirror forming part of the corrector. It has a long focal length of 1,500mm giving a focal ratio of f/11.8.

VERDICT

ASSEMBLY	★★★★½
BUILD AND DESIGN	★★★★
EASE OF USE	★★★★½
FEATURES	★★★★½
OPTICS	★★★★
OVERALL	★★★★½

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FIRST **LIGHT**

See an interactive 360° model of this scope at **www.skyatnightmagazine.com/pn210mkII**

Explore Scientific PN210 Carbon Mk II imaging Newtonian

Does the new PN210 build on the strengths of its predecessor?

WORDS: PETE LAWRENCE

VITAL STATS

- **Price** £849
- **Optics** 210mm (f/3.8) Newtonian reflector
- **Focal length** 800mm (f/3.8)
- **Focuser** 2.5-inch Hexafoc Deluxe with 10:1 fine-focus
- **Extras** 8x50 finder, carry bag, 2-inch extension tube, tube ring camera attachment
- **Length** 790mm
- **Weight** 9.5kg with all accessories (6.75kg without)
- **Supplier** Telescope House
- **www.**telescopehouse.com
- **Tel** 01342 837098

WWW.THESECRETSTUDIO.NET X 4

We reviewed the Explore Scientific PN210 Mk I in September 2014 and found it to be an excellent grab-and-go scope for astrophotography, despite a few issues with key elements such as secondary collimation. We now have the PN210 Mk II, but has it retained the practicality and portability of its predecessor?

SKY SAYS...
This is a portable and practical scope but requires careful tweaking to get the best results

The Mk II is a fast Newtonian reflector with a 210mm parabolic primary mirror working at f/3.8. Although designed with astrophotography in mind, it can be used for visual observing too. A view of the M42 region in Orion's Sword using a 20mm eyepiece (40x magnification) revealed sharp stars in and around the main nebula. All four of the Trapezium Cluster's main stars could be clearly seen, shining like bright jewels. Plenty of tenuous nebulosity was visible around the outskirts of the nebula too, giving a very pleasing view.

The optimisations for astrophotography include an oversized secondary mirror with an 85mm minor axis, to allow full illumination of large photographic sensors, and a construction that uses low-expansion materials to reduce focus issues caused by temperature changes.

The Mk I's excellent portability carries through to the Mk II. The scope is light, making it easy to transport and lift onto a mount. Both tasks are made easier thanks to a carry handle on its tube rings. A universal 44mm dovetail is supplied and is compatible with Synta/Vixen mount clamps. The main tube is made from carbon-fibre, a material that's light, strong and thermally stable. The primary and secondary mirrors also share low thermal-expansion properties.

Accuracy and adjustment

As this is a Newtonian telescope it will show coma towards the edge of the field. This manifests as tiny, comet-like tails attached to stars, pointing away from the centre of the field of view. Coma can largely be corrected by fitting a matching field-flattener, although this can be a relatively expensive add-on relative to the cost of a scope.

Accurate collimation is important for a fast-imaging Newtonian such as this. The PN210 Mk II's updated and simplified secondary collimation system consists of three thumbscrews. These are quick and easy to adjust, which is helpful as regular adjustment seems necessary. A gentle touch is also required to get the best results.

The primary cell has also been redesigned and offers three large spring-loaded adjustment knobs, each paired with a locking screw. In use, this ▸

FAST LIGHT COLLECTION

The 210mm parabolic primary mirror at the heart of the PN210 Mk II works at f/3.8. This is considered a fast focal ratio, a photographic term that essentially describes how quickly a certain depth of image can be delivered. One major benefit of a fast system is that exposure times can be kept relatively short. This also goes hand-in-hand with the excellent portability of the telescope. Transport it to a dark-sky location and even with moderately accurate polar alignment, it should be possible to take relatively short but still quite deep exposures.

The 800mm focal length of the primary mirror delivers a fairly wide field of view at prime focus. Using a Canon EOS 6D, a full frame DSLR, our images covered a sky area 2.5x1.5°. Consequently, the fast, wide-field delivery of the PN210's optics makes it best suited for the imaging of extended deep-sky objects.

Being a Newtonian reflector, the PN210's field does suffer from coma, which becomes very noticeable towards the edge of frame, especially when using a camera with a large sensor. A matching field flattener is recommended to reduce this issue.

CARBON-FIBRE TUBE AND RINGS

The PN210 Mk II has a strong carbon-fibre tube. As well as being light, easy to carry and easy to mount, the tube has low thermal-expansion properties. This helps maintain focus throughout temperature changes that occur at night. The matching tube rings have a convenient carry handle, which aids portability.

FOCUSER

The PN210 Mk II is fitted with a 2.5-inch Hexafoc DeLuxe focuser. This accepts 2-inch equipment or 1.25-inch barrels via a supplied adaptor. The focuser's internal diameter is overly large to avoid vignetting. A 10:1 speed-reduction knob allows you to attain an accurate final focus position. The focuser cannot be rotated.

FINDER

The unsung hero of many telescope setups is the finder and a good one is essential for a positive experience. The 8x50 finder supplied has an illuminated reticule to make precise pointing even easier. The finder is held by two rings each fitted with three screws, one set being adjustable.

FIRST LIGHT

SKY SAYS...
Now add these:
1. Explore Scientific coma corrector
2. Low profile Canon T-ring
3. Explore Scientific 24mm 82° 2-inch eyepiece

▸ arrangement felt a little imprecise. Although we could get to what looked like perfect collimation, even gentle application of the locking screws could mess this up. Our best and most precise results were obtained by collimating on the fly before each session. Fortunately, the large adjustment knobs on both primary and secondary mirrors made this a fairly easy task.

Finding focus

While image testing, as well as the expected diffraction spikes from the scope's four-vane spider, other diffraction effects appeared too. Bright stars were surrounded by 'light-sectors' interrupted at 120 intervals by 'shadows', presumably caused by the three sturdy clips retaining the primary mirror.

The PN210 Mk II uses a 2.5-inch Hexafoc Deluxe focuser with a larger than usual opening to reduce vignetting effects. The focuser also offers a 10:1 speed-reduction knob to help you achieve final, accurate focus. The main body of the focuser feels robust and can be adjusted in terms of focuser tension. But once focus has been achieved, there's no facility to rotate an attached camera. There are thumb and grub screws near the focuser base but no mention in the instructions as to what they're for. Speaking of instructions, we were disappointed to see that those supplied with the PN210 Mk II were for the Mk I model.

The PN210 Mk II is a portable grab and go scope. Its fast, f/3.8 optics allow you to go deep with relatively short exposures. But it still feels tricky to get and hold collimation – an essential element to a fast Newtonian. There's also the question of whether a field-flattener should have been included, given that it is a photographic Newtonian; without one, there's coma visible and an interrupted radial diffraction pattern around bright stars. Great shots are possible with patience – but it takes a bit of careful tweaking to get the best results. Ⓢ

WWW.THESECRETSTUDIO.NET X 2, PETE LAWRENCE

VERDICT

BUILD AND DESIGN	★★★★☆
EASE OF USE	★★★½☆
FEATURES	★★★★☆
IMAGING QUALITY	★★★½☆
OPTICS	★★★★☆
OVERALL	★★★★★

SECONDARY MIRROR AND COLLIMATION

An oversized, 85mm minor-axis secondary mirror ensures that large sensors are fully illuminated. The mirror is made of borosilicate glass, which has low thermal-expansion properties. Secondary collimation has been simplified for the Mk II and now consists of three thumbscrew adjustments – simple, but effective and stable.

PRIMARY MIRROR AND COLLIMATION

The PN210 Mk II uses a 210mm parabolic primary mirror made from low-expansion borosilicate glass. Low thermal expansion means the mirror is better at maintaining its optical figure during changes in the outside temperature. The primary is held securely in a cell, collimated by three hand-adjustable knobs, each paired with a locking screw.

▾ The Orion Nebula, imaged with a combination of a 20-second and a six-second exposure with a Canon EOS 6D at ISO 3200

FIRST **LIGHT**

Astro Pixel Processor deep-sky processing program

One-stop software that preps your raw deep-sky data for final tweaking

WORDS: SARA WAGER

VITAL STATS

- **Price** Owner licence €125; renter licence €50; free 30-day trial
- **Features** Pre-processing, full integration, cropping, light pollution removal, mosaic merging, processing via a digital development process algorithm
- **Updates** Free with renter licence; holders of owner licences will need to pay for significant updates
- **Minimum system requirements** Dual processors, 100GB free disk space, 4GB RAM, 64-bit OS, 1,280x768 screen resolution
- **Recommended system requirements** Quad processors, 250GB free disk space, 8GB RAM, 64-bit OS 1,680x1,050 screen resolution
- **Developer** Aries Productions
- **www.** astropixelprocessor.com

Astro Pixel Processor (APP) is the new kid on the astrophotography block, released in June 2017 and developed to make deep-sky image processing as easy as possible. This piece of software can be used for calibration, registration and integration as well as final processing. This is not revolutionary, but the ease with which it can be done is APP's biggest selling point. And it does give very good final images in the simplest format we have yet seen.

APP works best when used on a computer with the recommended specs. A solid state drive will allow APP to work much quicker than a standard hard disc drive, and if you are looking at combining images into large mosaics there's a benefit to having more than 8GB of RAM. Installers for Linux (DEB & RPM), Windows and MacOS (DMG) are available. Once installed, setting up the program is easy. After purchase a licence code is emailed to you, and all you have to do to get started is enter it into the Info tab on the top left of the opening screen.

The user interface may seem rather strange to begin with. There are the pre-processing menus on the left-hand side. The centre of the screen is dedicated to your image. The lower part of the screen is the image console, showing your loaded images and which processes have been performed. The right-hand side of the screen is the processing side, which is controlled using sliders. Clicking on the light blue '?' button near the middle of the processing side brings up a useful help menu.

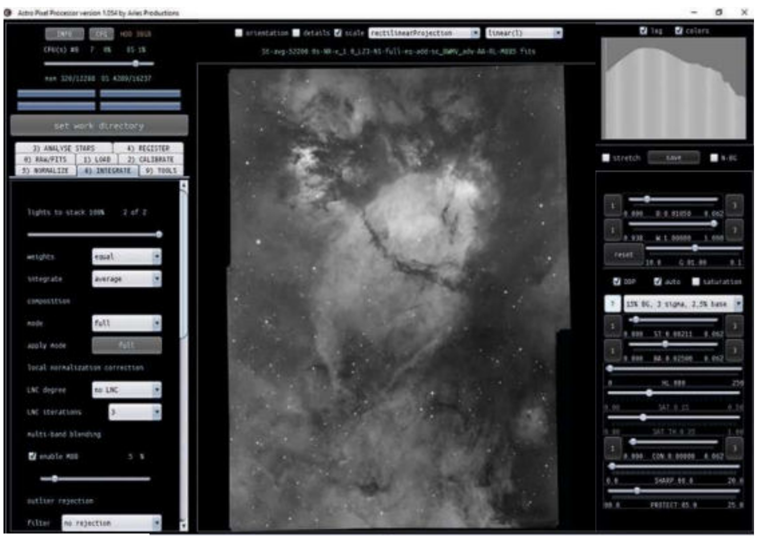
Get your frames ready

To get the best from the software and create the best final image, you will need calibration frames – these remove in-camera electronic noise, dust and vignetting in your imaging setup, and hot and cold pixels. It is straightforward both to make master calibration frames and a bad pixel 'map', which can be used instead of dark frames to remove hot and cold pixels.

Once you have loaded all your exposures, you are able to set the processing parameters specific to your needs. Most of these can be left unchanged, though if you are making a mosaic, or want to use a specific integration statistical method then you will need to select these from the Registration and Integration tabs. Then in one button press you will end up with a fully integrated stack of your ▸

MASTERFUL MOSAICING

The standout feature of this software has to be the mosaic integration feature. It uses a distortion modelling process to ensure that the panes fit together and that there are no pinched stars in the frame. Huge mosaics are supported and can seamlessly be stitched, and there's an option to use different cameras and optics within the same mosaic – a welcome inclusion if you want to collaborate with another imager or add data to increase the resolution of specific targets within the frame. The clever 'local normalisation correction' feature ensures that backgrounds and data of different panes are matched, which is vital in mosaics.

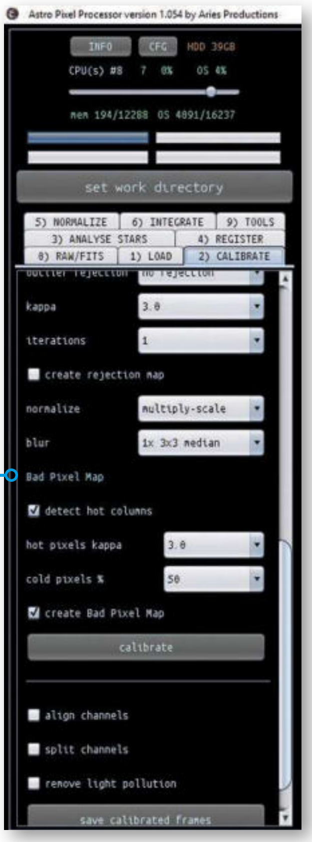


▲ **The mosaic integration feature can combine images taken with different cameras**

▲ **This image was edited entirely with APP – from registration and calibration to cropping and final processing using the automatic settings**

BAD PIXEL MAP

Upload five dark frames, five bias frames and five flat frames, and you can create a 'bad pixel map' using APP's Calibration tab. This can be saved and used for all images taken with the same equipment.



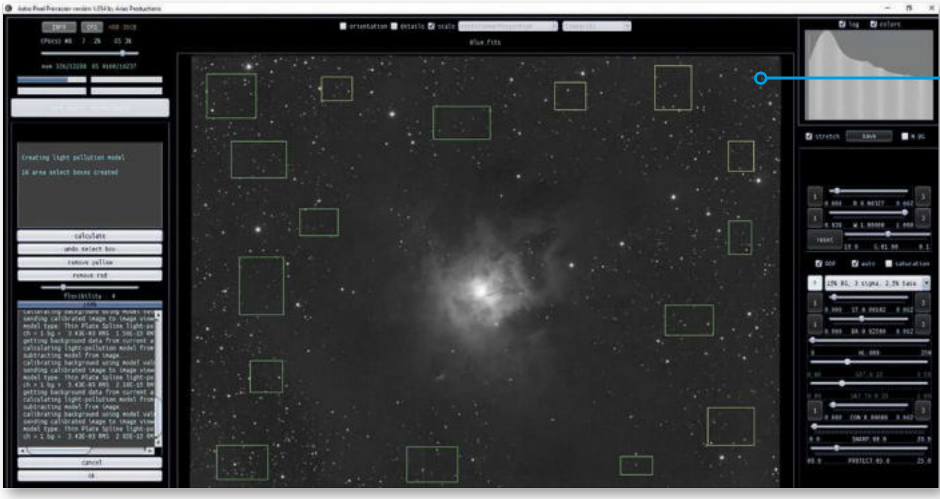
MEMORY USE CONTROL

With the CFG tab you can specify how much of your computer's RAM APP will use. This can help speed up the program, especially when it is carrying out memory intensive tasks such as processing large mosaics or stacking large image files.

MENU NUMBERING

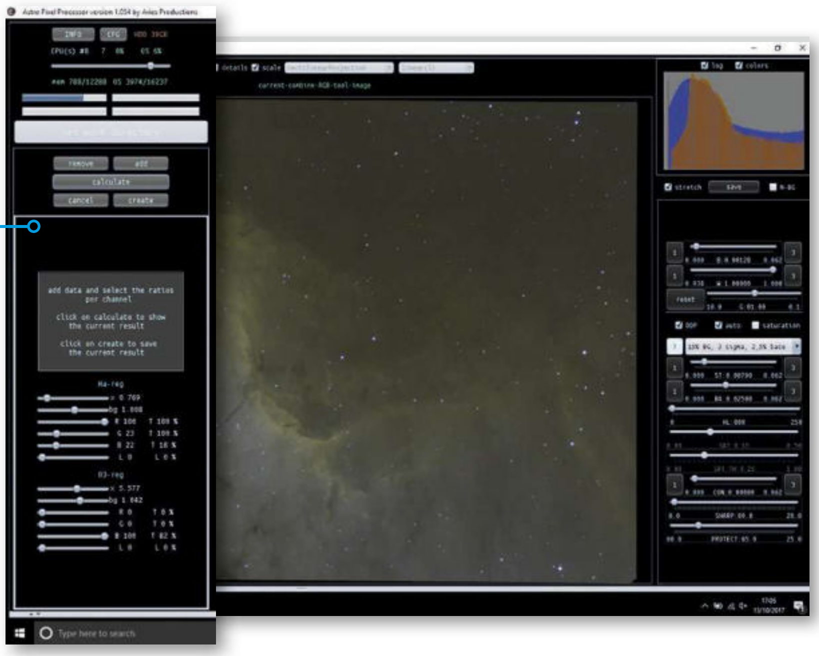
Each menu tab is numbered to help you do thing in the right order, should you want to run through the calibration process individually. Menus 1-6 deal with pre-processing whilst Menu 9 deals with the tools such as cropping and removal of light pollution.

FIRST LIGHT



LIGHT POLLUTION REMOVAL TOOL

The light pollution tool allows you to create selection boxes (a minimum of five) of any size around your image. Pressing 'calculate' will give you a view of how well it's worked; more boxes can be added if needed to better map the light pollution present, if any.



COLOUR COMBINATION TOOL

This is useful to use on monochrome data if you want a result that looks like a traditional Hubble colour palette. You can add Ha and OIII data into the red, green and blue channels in any strength you want, using the sliders to adjust the effect.

▸ data. If you are using a mono camera it is quickest to load in each filter set individually, save each final integrated stack and then load them in separately for alignment, cropping and so on.

The menu on the left-hand side gives access to tools for colour combination, light pollution removal, background calibration and other important processes. We found that the light pollution tool gave an even background, while the colour combination tool (which isn't needed if using a colour camera) had sliders that could strengthen the effect of one colour filter in relation to another. You can crop from the 'batch modify' menu and there is also a rotation tool, so there are plenty of options to work with an image.

Having used all the left-hand tools, you still have a linear and unprocessed image. You can easily process your image on the right-hand of the screen. We have found this to give very satisfactory results and deliver a good final image.

APP really is a competent all in one package with many excellent features and it is easy to use to get good results. One notable drawback is that comprehensive user instructions are not available, but the developer does offer excellent support, and there is an active forum on APP website and a number of video tutorials. There are two payment options available – annual and renter. For annual you pay a one-off fee of €125, but only minor software updates are included in that price, not major upgrades; for renter, you pay €50 annually, but are able to upgrade to any new version of APP as it becomes available. Ⓢ

VERDICT

VERDICT	
EASE OF USE	★★★★½
EXTRAS	★★★★☆
FEATURES	★★★★½
FUNCTIONALITY	★★★★½
INSTALLATION	★★★★½
OVERALL	★★★★☆

SKY SAYS...

1. Suitable computer
2. Astro imaging setup
3. Photo editing software for final tweaks

Books

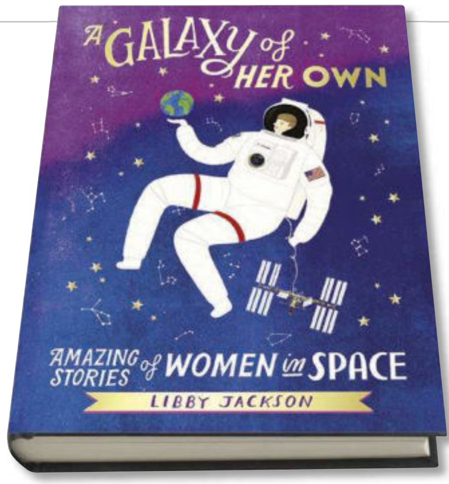
New astronomy and space titles reviewed

RATINGS

★★★★★ Outstanding
★★★★☆ Good
★★★☆☆ Average
★★☆☆☆ Poor
★☆☆☆☆ Avoid

A Galaxy of Her Own
Amazing Stories of Women in Space

Libby Jackson
Century
£16.99 ● HB



"With hard work and determination anyone can do anything," says Libby Jackson in her introduction. It sounds obvious, but it's a message that's easily forgotten in today's world of instant gratification and celebrity.

Jackson is proof of the statement: while at school she wrote to NASA for work experience and ended up in Mission Control at Houston. She's now programme manager for Human Spaceflight and Microgravity at the UK Space Agency.

Her book about 50 women who have contributed to our knowledge and exploration of space is beautifully presented and should appeal to all ages and genders. She devotes a spread to each woman, combining their stories with colourful portraits produced by students at the London College of Communication.

Helen Sharman was the first Briton in space and spent eight days orbiting Earth aboard Mir

HELEN SHARMAN ILLUSTRATION: SIYAKORN KIMHASAWAD

There's Émilie du Châtelet, the 18th-century French mathematician and physicist who worked all hours to finish her translation of Sir Isaac Newton's *Principia Mathematica* just days before giving birth to her daughter, only to die six days later. We also meet Mary Jackson, who in 1958 became NASA's first black female engineer. That she had to get a special permit to attend evening classes at university is a sobering reminder of the additional and enormous barriers to women of colour.

Not only does Jackson's book celebrate the contributions of women in space, it also illustrates the dizzying panoply of jobs involved. It includes tales of astronauts, doctors, software engineers, watchmakers, nutritionists and psychologists to name but a few.

Most crucially though, if it's meant to inspire the next generation, especially girls, I think it ably achieves this. My six-year-old daughter was all over the review copy the moment it arrived. "I love it," she said, "because it's all about space, and I love space!"

And if daughters need role models, a favourite section of the book was Jackson's profile on Eileen Collins, the first and only woman to command a Space Shuttle mission. Of Collins she writes: "Her three-year-old daughter, Bridget, thought that all mums flew spacecraft."

★★★★☆

SHAONI BHATTACHARYA *is a science writer and journalist*

TWO MINUTES WITH
Libby Jackson

How did you come to work at NASA Mission Control?
I was in Year 12 at school, aged 17. I had always been fascinated by space so I emailed NASA's Johnson Space Center to ask if I could visit them, never expecting that they'd agree. When they emailed back a few weeks later and said yes, I was gobsmacked and had to explain to my parents what I'd done! I'll never forget the first time I sat in Mission Control and watched a Shuttle simulation. I knew there and then that I wanted to work in Mission Control one day myself.

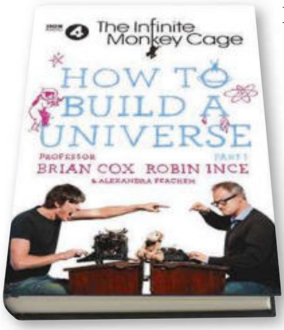
What was your aim in writing this book?
Spaceflight is still, sadly, quite a male-dominated arena and the history books even more so. But this is changing. Since the beginning, women have played their part in getting humans into space and it's important that their stories are told, to remind everyone that we achieve the best results by including everyone in our efforts. I hope the book will help readers, particularly young people, see that nothing is impossible.

Were there any important people you had to leave out of the book?
Space technology underpins our everyday lives, from satellite navigation to space exploration, from studying our atmosphere to the communications networks that keep us all talking to each other. There are so many more amazing scientists, astronomers, engineers and others who make these things possible, with countless amazing stories to be told.

LIBBY JACKSON *is the Human Spaceflight and Microgravity Programme Manager for the UK Space Agency*

How To Build A Universe: Part 1

Prof Brian Cox, Robin Ince and Alexandra Feachem
William Collins
£20 ● HB



BBC Radio 4's *The Infinite Monkey Cage*, hosted by Brian Cox and Robin Ince, is hugely popular (and in many ways unique) with its mix of comedy, celebrity guests and light-hearted debunking of the scientific world.

How To Build A Universe represents an attempt to transfer that format to the printed page, but unfortunately fails. Occasionally funny, often informative, but ultimately disappointing, the fan of the radio show will feel somewhat cheated by this book, while those unfamiliar with the format will come away feeling frustratingly perplexed.

Although the book could have been half the size without the overindulgent use of whole-page quotes from its own text, in unfeasibly large fonts, there is some interesting content.

Cox and co. discuss the origins of the Universe, gravity, dark matter, dark energy, particle physics, space exploration, paranormal phenomena and so on, all with an admirable drive and enthusiasm. Eric Idle's short preface is an inspired highlight of irreverence. But the conversation that makes up the book is just that: a conversation, which often detracts from the subject at hand.

For the serious armchair scientist there are far more informative and fascinating (even humorous) accounts of modern astrophysics available at the book shop. For the fan of irreverent comedy there is also a plethora of printed matter to choose from. Putting these two things together in print was always going to be difficult. And unfortunately, even though the BBC radio show is rightly praised, the attempt at an accompanying book is not a success.

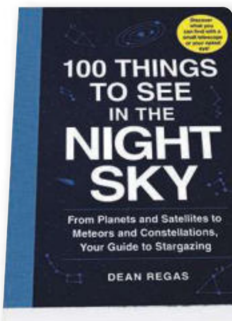
★★☆☆☆

ALASTAIR GUNN *is a radio astronomer at Jodrell Bank Observatory*

100 Things To See In The Night Sky

BOOK OF THE MONTH

Dean Regas
Adams Media
£10.99 ● PB



Anyone starting out in stargazing would benefit from a knowledgeable and friendly guide to point out exactly what can be seen with the naked eye, and that is what *100 Things To See In The Night Sky* sets out to be.

The book is divided into three major observing sections: 'Sun, Moon & Planets', 'Stars & Constellations' and 'Beyond Stargazing'. For each, there are instructions on how to find the target, a description of it and an indication of how difficult it is to find and observe. Regas's writing style is informal, simple and clear, and he enhances his descriptions with references to a wide range of mythologies. His charts and diagrams also have a welcome simplicity and clarity.

There is also a comprehensive index so if, for example, you can't remember which constellation description includes a Shawnee myth, you can easily find it.

There are a few niggles for UK readers, however. Temperatures are given in Fahrenheit, some descriptions are latitude-dependent (Dubhe getting too low to be seen above the horizon) and there are inconsistencies in the indicated ease of observation (Delphinus is classed as moderate, but the brighter Cepheus as difficult, for example).

Ultimately though, if you were to work your way through *100 Things To See In The Night Sky*, you too could make a significant stride towards developing the same thorough familiarity exemplified in its pages. The book's niggles are easily outweighed by its positives and it would make an ideal naked-eye guide for anyone over the age of 10.

★★★★★

STEVE TONKIN *writes* BBC Sky at Night Magazine's *monthly Binocular Tour*

The Quiet Revolution of Caroline Herschel: The Lost Heroine of Astronomy

Dr Emily Winterburn
The History Press
£20 ● HB

As a female astronomer working in the 18th century, a comet hunter and the first woman to have a paper read at the Royal Society, Caroline Herschel kept meticulous diaries, notebooks and journals, detailing her domestic and scientific endeavours. Yet she deliberately destroyed all her records for the years from 1788 to 1797, her most productive decade of astronomical discovery.

This book sets out to fill in those lost years, when she discovered eight comets and established her scientific reputation, while also supporting her brother in his own astronomical work, helping his wife with their domestic arrangements and the upbringing of her young nephew. All this is set against the backdrop of social and political upheaval, and scientific advances, both here and on the Continent.

The Quiet Revolution of Caroline Herschel ultimately gives its readers no great revelations and a lot of repetition. Herschel led a quiet life, working hard and dedicated to her family. She was modest and shy of strangers, yet determined to gain her independence and recognition for her work. To do so she had to negotiate the minefield of social and scientific etiquette of the time.

Overall the book does little to shed much new light on Caroline's life. Perhaps most frustratingly of all, the mystery of why Caroline would deliberately destroy all her journals for the most productive decade of her life, is never resolved.

★★★☆☆

JENNY WINDER *is a science writer, astronomer and broadcaster*

Gear

Elizabeth Pearson rounds up the latest astronomical accessories

1 Baader Hydrogen-Alpha Narrowband CCD Filter

Price: €140 • **Supplier:** Teleskop Service
www.teleskop-express.de
Use this unmounted filter for in a filter wheel or slider and combine it with OIII and SII filters to create sharp false-colour images with reduced fringing.

2 Homestar Original Planetarium

Price: £98 • **Supplier:** Sega Toys
www.segatoys.space

Bring the Milky Way to your home with this planetarium projector. Swap the image disc to change the view or enjoy your own personal meteor shower with the shooting star function.

3 Secondary Mirror Dew Heater

Price: £24 • **Supplier:** 365 Astronomy
www.365astronomy.com

Keep the dew off your secondary mirror with this heater. It requires a 12V power supply, but use of a dew controller is optional.

4 Omegon Panorama 2 Eyepieces

Price: €229 • **Supplier:** Omegon
+49 8191 940490 • www.omegon.eu

Enjoy a 100° field of view through high-quality glass that increases sharpness and contrast. The waterproof casing prevents damage.

5 The Farthest

Price: £10.99 • **Supplier:** HMV
store.hmv.com

This award-winning documentary charts the journey made by the twin Voyager probes to the farthest reaches of the Solar System and beyond.

6 ZWO Off-Axis Guider Adaptor

Price: £117 • **Supplier:** Telescope House
www.telescopehouse.com • 01342 837098

If your telescope is too large to use a traditional guidescope, this adaptor provides a rigid base for a guidescope or camera and can be adjusted in all three axes.

WHAT I REALLY WANT TO KNOW IS…

What gives a galaxy its shape?

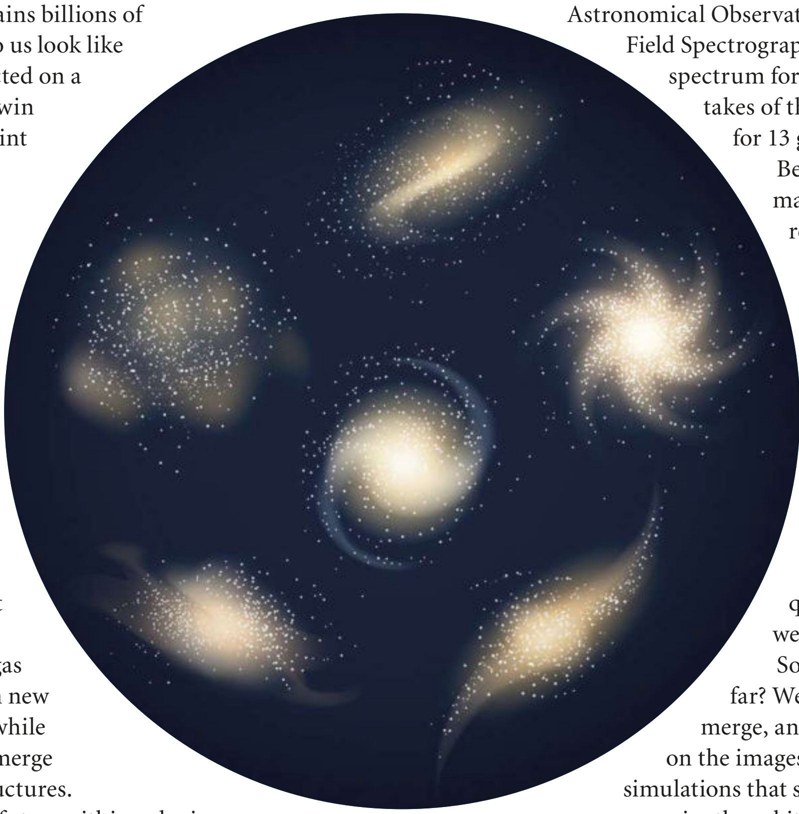
Caroline Foster is studying stellar motions in hundreds of galaxies to determine how their structures form and evolve

INTERVIEWED BY PAUL SUTHERLAND

The Universe contains billions of galaxies, which to us look like flat images projected on a screen. When Edwin Hubble proved that these faint blurs were separate galaxies beyond our Milky Way a century ago, he wondered about their true shapes. Astronomers have pondered this problem for decades but have been unable to find answers. It is important that we do, because knowing a galaxy's shape can help us to learn how it formed and evolved.

Some galaxies are like flat discs, others like squashed rugby balls. We think that gas falling into a galaxy to form new stars leads to a flatter disc, while galaxies which collide and merge produce more spherical structures.

Looking at the motions of stars within galaxies can help us to infer what their form is. That has been recognised for a long time, but the necessary data was not there. I realised that the latest technology now allows us to collect this data, and to do so from large numbers of galaxies. This gives me a large enough sample to get an idea of how galaxies are shaped according to factors such as how fast they rotate.



Though many galaxies share common features such as arms and bars, there is no 'standard' when it comes to shape

ISTOCK

Going three dimensional

To reveal the shapes of galaxies, I measure the motions of the stars. That gives me the full dynamics of the stars in 2D, so I can see how different groups of stars move within a galaxy. When I have that data for the many positions in one image, I can see how the whole galaxy is rotating, and that helps me to picture the galaxy in three dimensions.

My work on this project is carried out at the Australian Astronomical Observatory, in New South Wales. The Anglo-Australian Telescope, with its 3.9m mirror, has a clever piece of kit attached called SAMI – the Sydney Australian Astronomical Observatory Multi-Object Integral Field Spectrograph). It is able to obtain a spectrum for each point in an image it takes of the sky, but it can do that for 13 galaxies at a time.

Being able to measure so many galaxies in one go is really key to the project's success. It made me realise that SAMI could revolutionise this field of research. For the first results reported from this project, we observed 845 galaxies, but we had collected more than 1,000 measurements. They don't all have the right signal-to-noise quality that we need, so we had to reject some.

So what have I found so far? We know that galaxies merge, and we've seen mergers on the images. There are some simulations that show us how mergers can reorganise the orbits of stars, and if the orbits of stars are reorganised then that is going to change the shapes intrinsically of those galaxies. These merging galaxies typically don't have fuel for further star formation, so we just see a reorganising of the present stars' orbits. But other galaxies still have a lot of gas in or around them, and that gas can collapse and create new stars, and that will change its shape as well. It can even reform a disc. So depending on the different things that come into play, you expect to have different shapes.

My first results show that the obvious thing to affect a galaxy's shape is its rate of spin. If it spins very fast, then it will become very flattened and produce a quite circular disc. On the other hand, galaxies that rotate very little, or not at all, have more varied shapes, like squashed balls or sea urchins.

I plan to build on this study by seeing how a galaxy's local environment affects its shape, and how shapes change with age. Such research should also help inform us about such things as the dark matter around galaxies.

ABOUT CAROLINE FOSTER

Dr Caroline Foster is an astronomer based at the University of Sydney. Her research interests include the formation and evolution of structure in the Universe, including globular clusters, galaxies and cosmological voids.

THE SOUTHERN HEMISPHERE IN JANUARY

With Glenn Dawes

WHEN TO USE THIS CHART

1 JAN AT 00:00 UT
15 JAN AT 23:00 UT
31 JAN AT 22:00 UT

The chart accurately matches the sky on the dates and times shown. The sky is different at other times as stars crossing it set four minutes earlier each night. We've drawn the chart for latitude –35° south.

JANUARY HIGHLIGHTS

On the night of 31 January a total lunar eclipse is visible across Australia. From the eastern states the partial phase begins at 21:48 EST, with totality at 22:51 EST. Earth's central shadow covers the entire Moon until 00:08 EST, with the partial phase ending at 01:12 EST. The Moon moves south of the centre of this umbral shadow so its northern limb may show a darker shade of red, compared to the south. From Western Australia, totality happens around the end of twilight (20:51 WST).

STARS AND CONSTELLATIONS

Many bright stars can be seen this evening, but what we call a 'bright star' might just look that way because it is nearby. If the 20 brightest stars in the entire sky were all 32 lightyears away (the distance at which we measure absolute magnitude) five of them, visible in the late evening in January, would truly stand out. Canopus (Alpha (α) Carinae), Rigel (Beta (β) Orionis), Betelgeuse (Alpha (α) Orionis), Acrux (Alpha (α) Crucis) and Hadar (Beta (β) Centauri) would all be brighter than Venus.

THE PLANETS

The only planetary representatives in the evening sky are Neptune, which sets around 22:00 EST mid month, and Uranus, which follows two hours later. By mid month four planets are visible in the morning sky. Mars and Jupiter rise around 01:00 EST, moving to 0.25° apart on the 7th. Mercury is visible low in the eastern dawn sky. The innermost planet is passed by Saturn as it rises into the morning sky, and these two are separated by only 0.7° on the 13th.

DEEP-SKY OBJECTS

Orion dominates the northern evening sky. The most eastern (rightmost) member of his Belt is the brilliant triple star Alnitak (Zeta (ζ) Orionis; RA 5h 40.7m, dec. –01° 57m). The brightest member (mag. +1.7) has an obvious, fainter (mag. +9.5) companion a comfortable 1 arcminute away. Increase the power to at least 200x and, under good seeing, you'll see the main star splits into two blue ones (mag. +1.9 and +3.7), 2.2 arcseconds apart.

Alnitak sits on the edge of the bright Flame Nebula, NGC 2024 (RA 5h 41.6m, dec. –01° 51m; pictured). This mottled emission cloud is hard to see against the star's glare, so it's best to move the star out of the field. The nebula is almost dissected by a dark band, with a subtler branch running eastward.

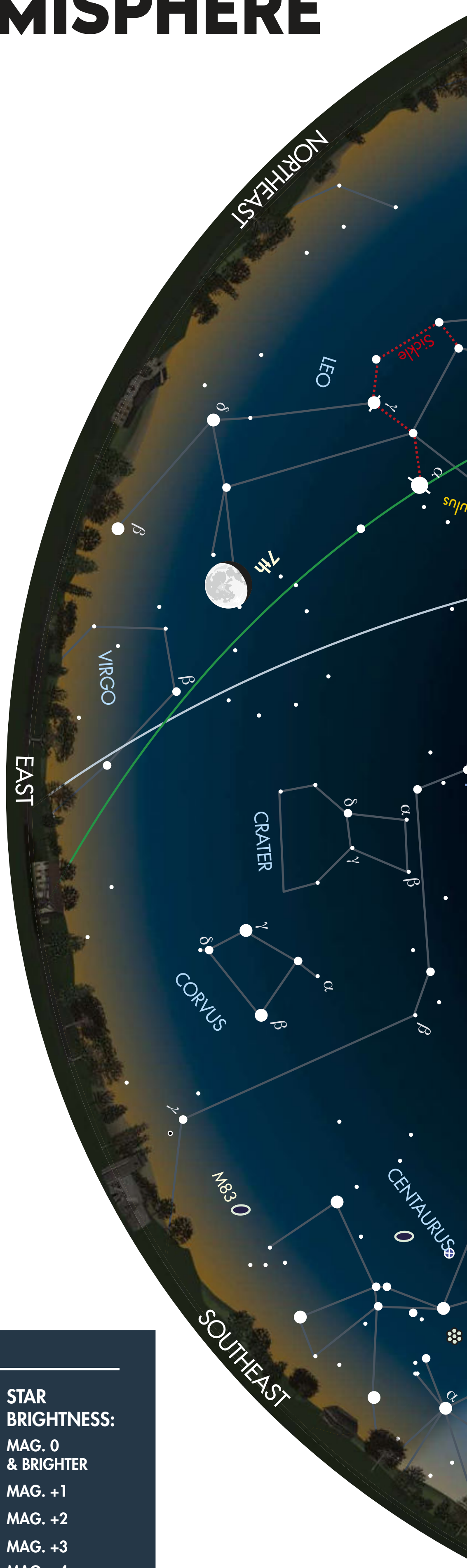
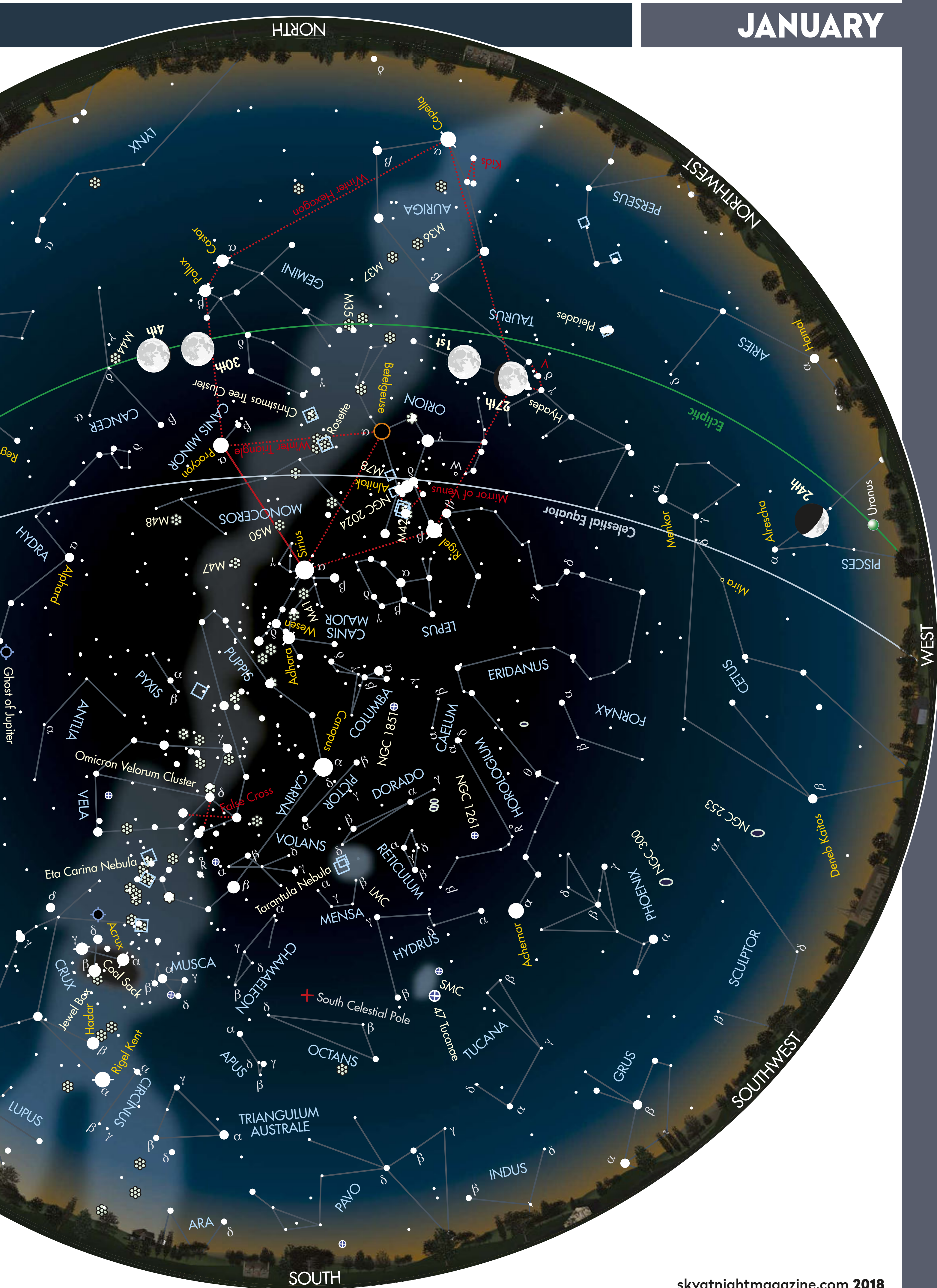


CHART KEY

- GALAXY
- OPEN CLUSTER
- GLOBULAR CLUSTER
- PLANETARY NEBULA
- DIFFUSE NEBULOSITY
- DOUBLE STAR
- VARIABLE STAR
- COMET TRACK
- ASTEROID TRACK
- METEOR RADIANT
- QUASAR
- PLANET

STAR BRIGHTNESS:
- MAG. 0 & BRIGHTER
- MAG. +1
- MAG. +2
- MAG. +3
- MAG. +4 & FAINTER

CHART: PETE LAWRENCE, IMAGE: FRANZ KLAUSER/CCDGUIDE.COM


NORTH
NORTHWEST
WEST
SOUTHWEST
SOUTH
LYNX
Capella
Kids
Winter Hexagon
AURIGA
PERSEUS
M36
M37
Castor
Pollux
GEMINI
M35
TAURUS
Pleiades
ARIES
Hamal
M44
4th
30th
1st
27th
Hyades
Ecliptic
CANCER
Christmas Tree Cluster
Betelgeuse
ORION
Rosette
CANIS MINOR
Procyon
Winter Triangle
M78
Alnitak
Mirror of Venus
Celestial Equator
Menkar
Alrescha
24th
Uranus
MONOCEROS
M48
M50
NGC 2024
M42
Rigel
Sirius
PISCES
HYDRA
Alphard
M47
M41
Mira
CANIS MAJOR
LEPUS
Wesen
Adhara
PUPPIS
Ghost of Jupiter
ERIDANUS
CETUS
PYXIS
COLUMBA
NGC 1851
CAELUM
FORNAX
ANTLIA
Canopus
HOROLOGIUM
Omicron Velorum Cluster
VELA
CARINA
PICTOR
DORADO
NGC 1261
NGC 253
False Cross
Deneb Kaitos
NGC 300
VOLANS
RETICULUM
PHOENIX
Eta Carina Nebula
Tarantula Nebula
LMC
MENSA
Acrux
Achernar
MUSCA
HYDRUS
CRUX
Coal Sack
CHAMAELEON
SCULPTOR
Jewel Box
South Celestial Pole
SMC
Hadar
47 Tucanae
TUCANA
Rigel Kent
OCTANS
APUS
GRUS
CIRCINUS
LUPUS
TRIANGULUM AUSTRALE
INDUS
PAVO
ARA